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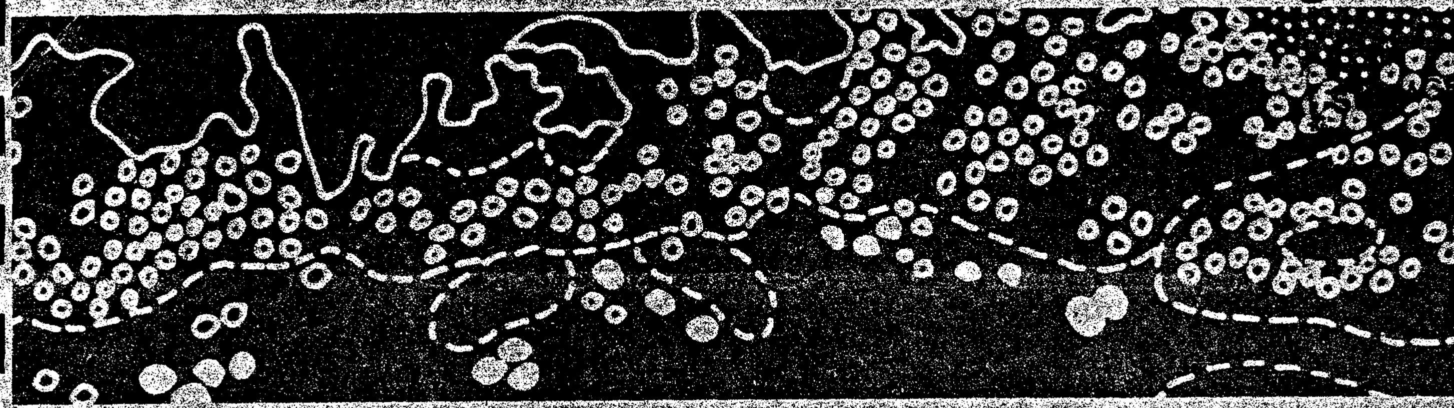
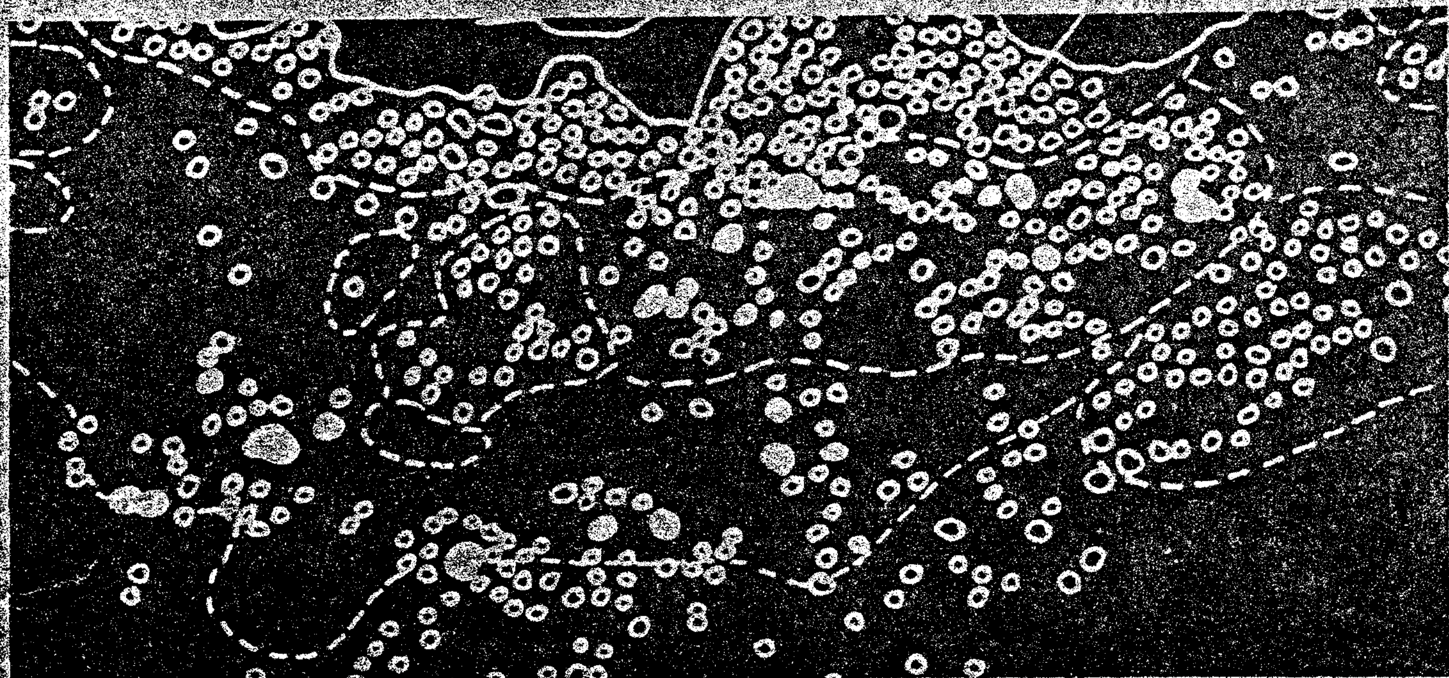


PUBLIC USE EFFECTS IN THE CABRILLO NATIONAL MONUMENT INTERTIDAL ZONE

1978 Project Report



Prepared under the direction of Dr. Joy B. Zedler, Biology Department, San Diego State University, San Diego, CA 92182

FOR

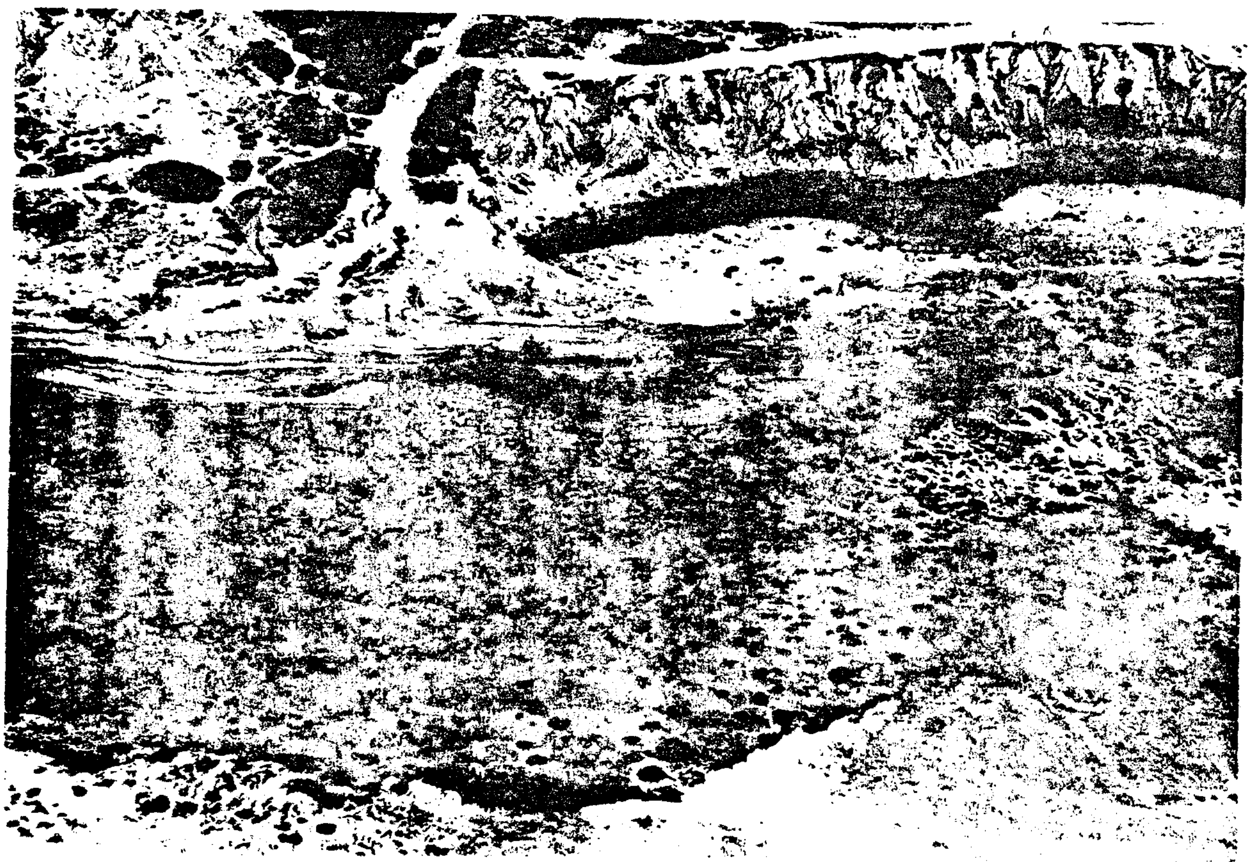
THE U.S. DEPARTMENT OF INTERIOR NATIONAL PARK SERVICE

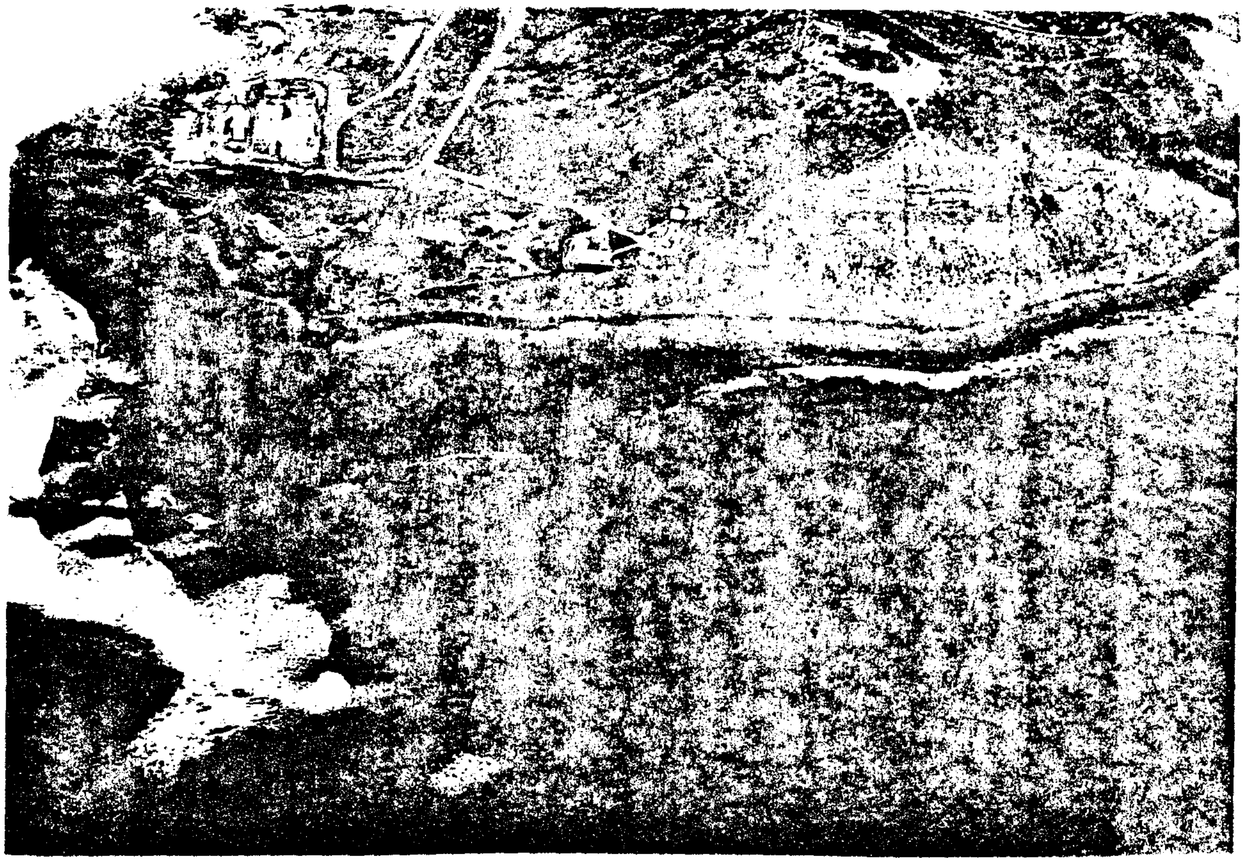
CONTENTS

February, 1978

Above: General view of the west coast of Cabrillo National Monument.

Below: Close-up of the "New Access" where visitors reach the intertidal zone.





Above: General view of the southern coast of Cabrillo National Monument.

Below: The southeastern coast of Cabrillo National Monument (adjacent above).

Introduction:

This report summarizes the results of the 1977 project at the Cabrillo National Monument (CNM) Intertidal Zone. The work is a continuation of the 1976 project (Zedler 1977) which documented the biological resources of several intertidal habitats and examined differences in biota where people use was heavy and where it was light. Our general objectives in 1977 were to determine the levels and types of people use during low tides and to examine experimentally the effects of people use. In addition, we continued the monitoring of intertidal resources, completed a reconnaissance of the east and south coasts of CNM, and made additions to the 1976 total species list.

The results are presented in six parts, and four SDSU students were responsible for gathering data as listed below:

A. People use monitoring--Kathy Parker, undergraduate biology major

B. Effects of disturbance on intertidal biota--separate studies by Robert Shaver, James Lopez, and Mary Curtis, all ecology graduate students

C. Monitoring of resources--supervised by James Lopez, Robert Shaver and Mary Curtis

D. Reconnaissance of east and south coasts of CNM--James Lopez and Robert Shaver

E. Additions to CNM intertidal species lists--James Lopez and Robert Shaver

F. Management considerations and recommendations

The studies which are summarized in Part B have been written in separate report form to provide details of data and methods. These student reports are on file at the CNM Administration office. The trampling study of J. Lopez and the rock-turning study of R. Shaver will form the major portion of the students' masters' research, and upon conclusion the theses will be filed with CNM as well as the SDSU Library.

Zedler, Joy B., editor. Ecological Resource Inventory of the Cabrillo National Monument Intertidal Zone. 1977. Mimeograph.

A. People Use at Cabrillo Monument Intertidal Zone

The objectives in examining people use at Cabrillo's intertidal zone were 1) to determine the types of use, and 2) to determine the amount of use--in total, for different days, for different types of tides.

People use was monitored on 20 days during 1976-77 for approximately 3 hours each day, including at least one hour before and one hour after the predicted low tide. In all, 54.9 hours of observation were included in the study. Most days were weekends, but on four occasions, use was monitored on adjacent Fridays and/or Mondays.

Kathy Parker did the field work. Her procedure was to survey each of 5 areas near the intertidal access (noted 1-5 on Figure A1) at half-hour intervals on days of selected low tides. Numbers of people in each area were counted, and the types of activities were tallied. Assessing the activities of visitors is difficult, since many people are doing different things at once. Hence, we decided to tally only the occurrence of an activity, not the number of people doing it or the time spent doing it. That is, 30 people may have been poking anemones during the half hour period, but only one mark would be made on the data sheet. The results are thus general indicators of popular activities.

Types of activities. Five activities occurred very frequently: walking, standing, picking up animals, picking up plants, rock turning and poking anemones. For the survey as a whole, as well as for each area, the types of activities were compared to one another to determine the relative frequency of each type (Table A1).

Table A1. Relative frequency of activities in five areas of the Cabrillo intertidal zone. Data are percents.

Activity	Area 1	Area 2	Area 3	Area 4	Area 5	All areas
walking	36	63	45	45	42	44
standing	32	32	33	34	36	33
picking up fauna	17	2	11	10	12	11
poking anemones	8	2	5	4	3	5
rock turning	6	1	3	6	4	4
picking up plants	2	0	3	1	3	2

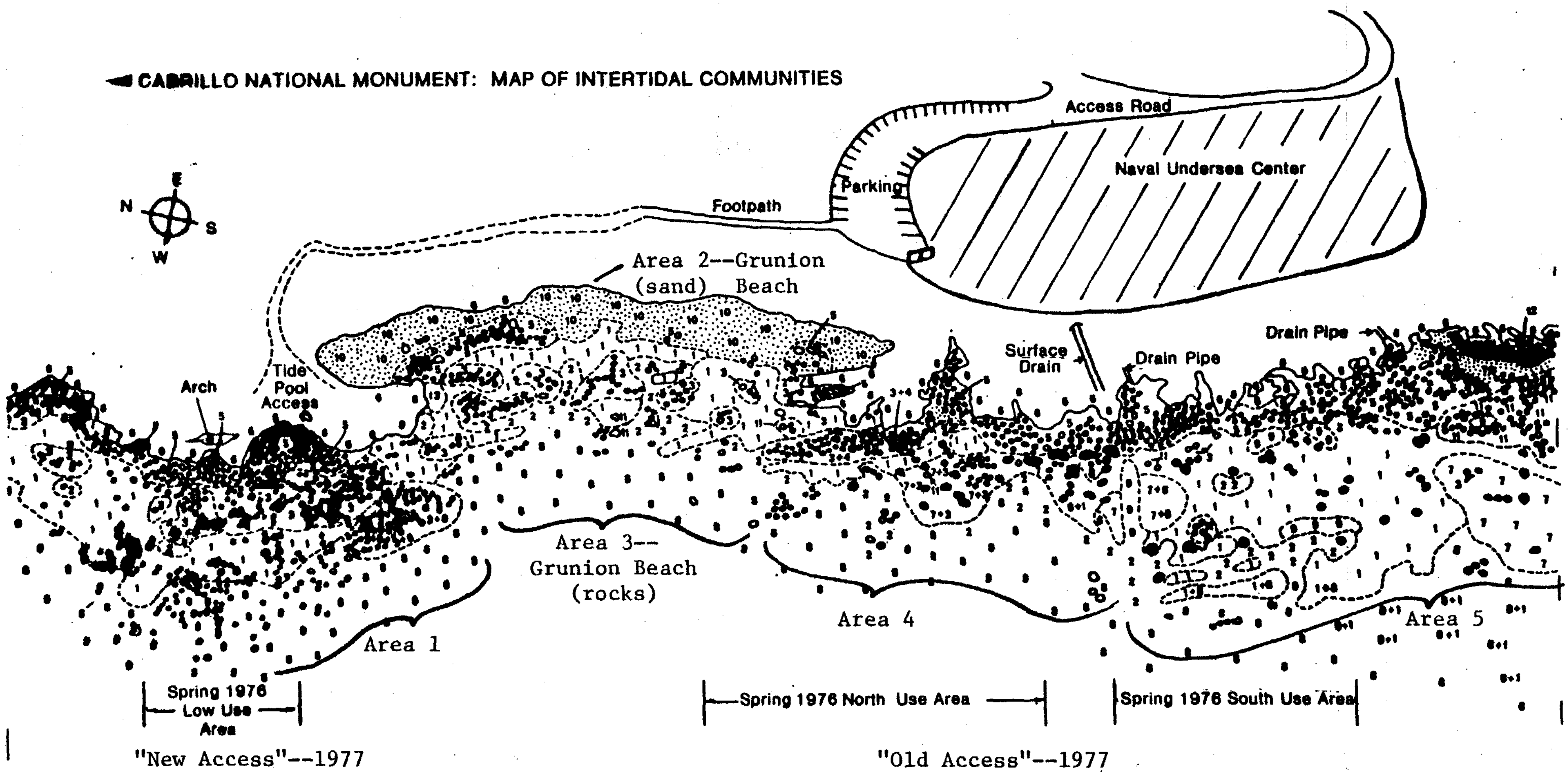


Figure A1. Location of Areas 1-5 used in sampling visitor use. This map is taken from the 1976 Project Report; it also shows the habitat types described therein.

Differences in activities for the five areas can be seen by comparing them to the relative popularity of those activities for all areas combined (last column of Table A1). Area 1 is the access route to the intertidal zone. Animals were more frequently picked up in this location. Area 2 is the sandy beach of the Grunion Beach area, and walking is the most frequent activity. The sandy area is little utilized for biological study. At the adjacent rocky area (Area 3), activities are similar to other rocky areas (4 is the former "North Use Area" and 5 is the former "South Use Area"). Visitors to the more distant areas tended to be organized groups. Organized groups tended to be more careful in their use of the intertidal zone then individuals. Overall, examination of animals is more popular than examining plants.

Several other activities were noted during the surveys, and they are listed below to indicate the range of usage that occurs in the intertidal zone. The list also indicates the types of damages that can occur. Noted at least once during the survey were: pulling at limpets on cliff face, pulling out Mytilus (mussels), attempting to remove abalone shell from area, harassing octopus, collecting data with transect lines, trying to catch crabs, removing crabs, trying to catch fish, pulling at gooseneck barnacles, putting animals into buckets, trying to catch lobsters by hand, pulling out Phyllospadix, pulling Pelvetia off rocks, plucking plants off rocks, pouring beer on Pelvetia rocks, battering algal mats with large pieces of kelp, chopping up Phyllospadix beds with machete, pulling off kelp, breaking off piece of cliff, lifting and turning rocks back, throwing rocks, picking up rocks, breaking rocks apart, using rocks as bouncing balls, sticking knife into tide pools, and throwing sticks. It is obvious from this list that animals, plants, and the substrate are all subjected to abuses. None of these activities occurred in the sandy beach area; most were noted near the intertidal access.

Amount of use. People use in relation to types of tides, location, day of week and time of day in general shows wide variability. We expected that the public would be aware of the dates for good low tides and that use would be greatest for the minus tides. This proved to be correct (Figure A2) The number of persons present at one time was averaged for all times censused on each day for each of the five areas sampled. The resulting scatter diagram (Figure A2) shows a general increase in use with lower tides. In part, the high variability results from differences in weather, with few visitors coming on days of bad weather.

Differences in use for the five areas can also be seen from Figure A2. Most of the high averages are in Area 1, nearest the access. Areas furthest from the access (4 and 5) are generally less frequently used. These results support another expectation, namely that people will utilize most heavily the areas closest to the access.

To determine if the users were more likely to visit the intertidal zone on a particular day, we monitored use for weekend and weekdays. We found a tendency for Sunday to be more popular than Saturday (Figure A3). Fridays are also popular, but use here may be more for educational than recreational purposes. We examined both the average number of people present and the average maximum number of persons present (Figure A3), and found the patterns to be similar.

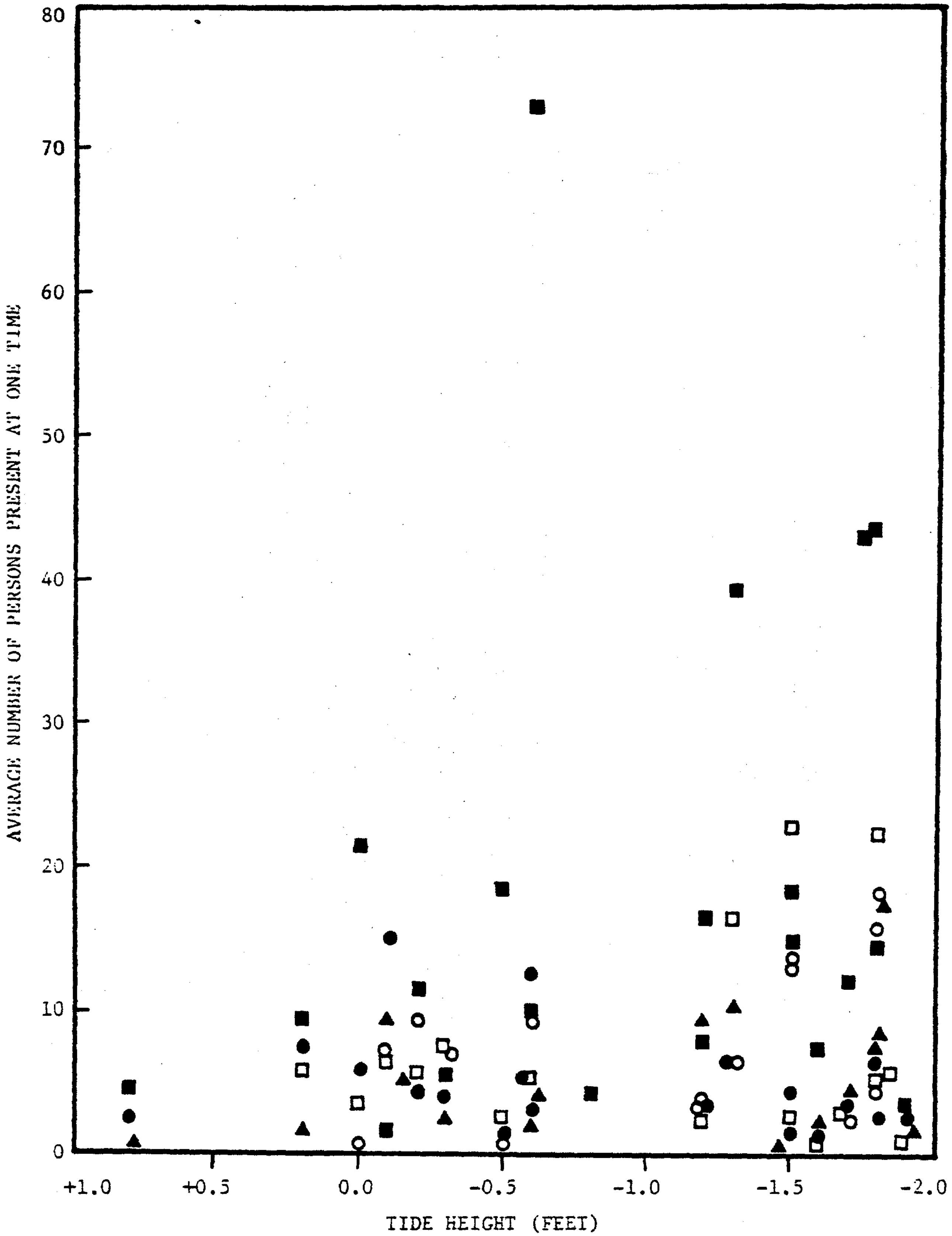


Figure A2. Visitor use in relation to tide height. Symbols are for the five areas which were monitored: Area 1 = ■; Area 2 = ●; Area 3 = □; Area 4 = ▲; Area 5 = ○. See figure A1 for Area locations.

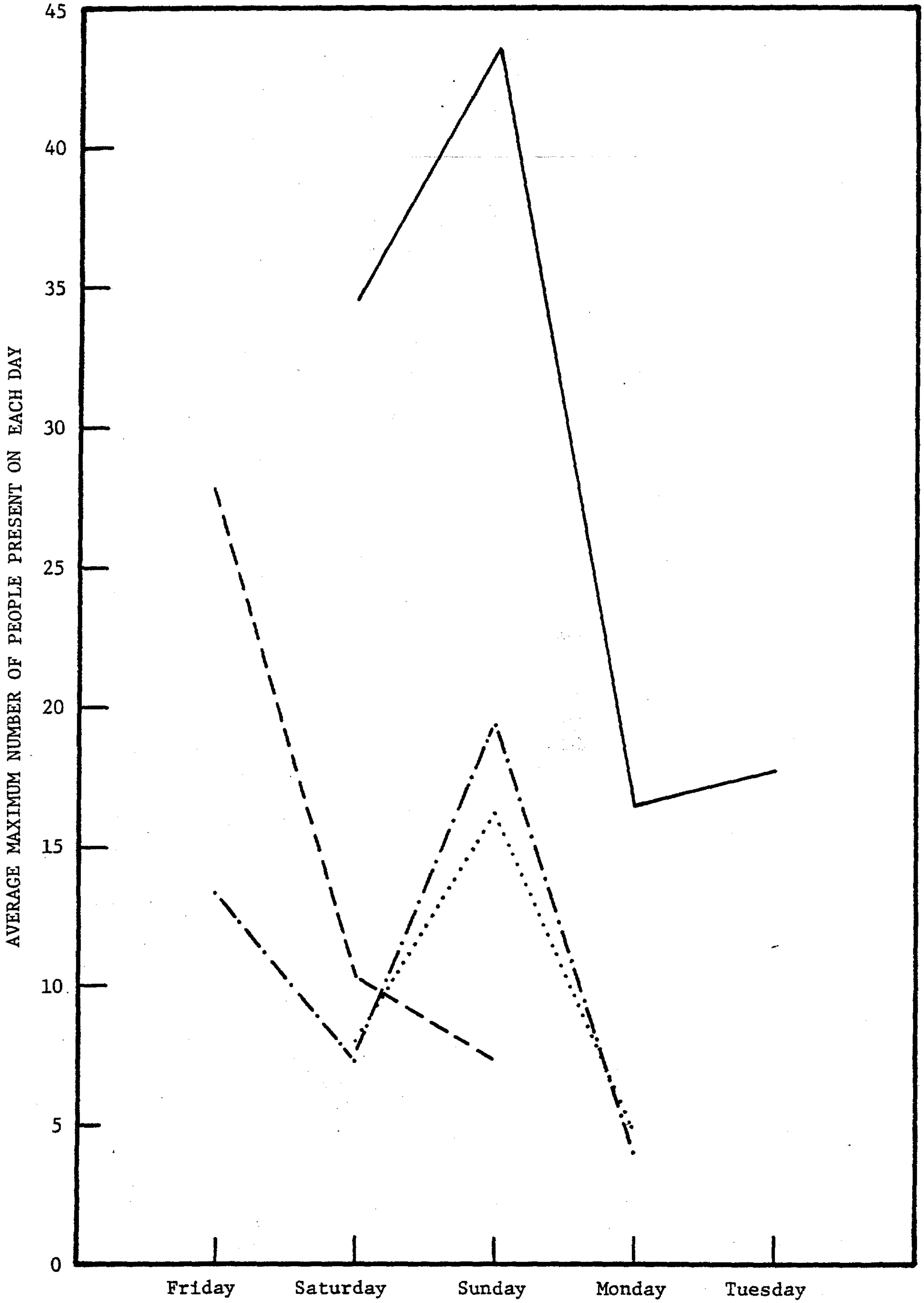


Figure A3. Visitor use in relation to day of week. Periods monitored were: November 20-23, 1976 ——— ; December 3-5, 1976 — — ; December 18-20, 1976 ····· ; January 14-17, 1978 —·—·. Data are averages of the maximum number of people present at any one time.

The timing of visits was also of interest to determine how closely tide tables are followed. Examining only the data for Sundays, we determined the total number of people present (summing numbers for all five areas) at each half-hour census. The results (Figure A4) show that use is related to time of low tide only in a general way; people seem to be aware of the good low tides but to time their visits when convenient in the mid-afternoon. Note from this figure that up to 160 people were found at a single time on November 21, 1976, and that densities of 50 or more are not uncommon.

Conclusions. Considerable variability in people use activities was found. However, the following patterns were noted.

1. A large number of activities detrimental to the intertidal habitat were recorded, from removing plants and animals to breaking up the substrate.

2. Most activity was concentrated near the access to the intertidal zone.

3. Use is heaviest with lower tides.

4. Sundays are more popular for visits than are Saturdays, but weekday use can be high (presumably due to educational activities).

5. Although visits are generally timed to the low tides, the largest use does not necessarily coincide with the predicted time of low tide. Convenience to the visitor would seem to be more important, since mid-afternoon was most popular on Sundays.

6. People use of the CNM intertidal zone is heavy and concentrated in the access area. The greatest effects of their visits should be felt near the access.

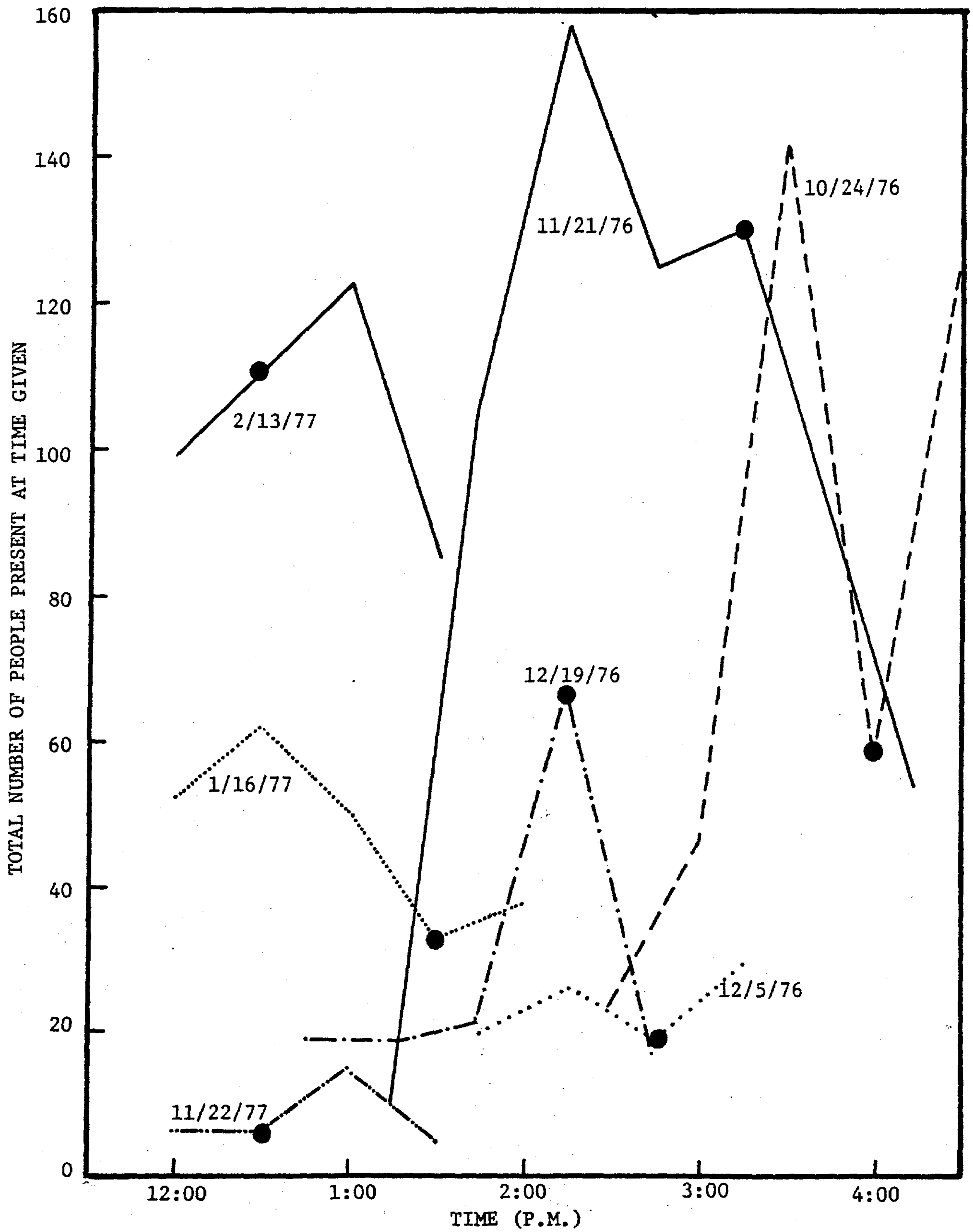


Figure A4. Visitor use in relation to time of day. All data are for Sundays. Solid circles represent the time of the lowest tide. Dates are given on each curve.

B. Experimental studies of human use

B. 1. Effects of trampling algal mats (a summary of the work by J. Lopez)

In order to determine the effects of visitor use on intertidal algal mats, trampling experiments were carried out first at Sunset Cliffs, and later at CNM. The location of the CNM experiments was near the "New Access." In both areas, the algal mats were sampled using the point method for percent cover to establish the pre-trampling community composition. The 12 stands at Sunset Cliffs were then assigned to controls (no trampling), 10 step, 100 step, and 400 step treatments. At CNM, only 10, 25, and 50 step treatments were performed to minimize disturbance to the area, since the Sunset Cliffs experiments had demonstrated that the threshold for damage occurred somewhere between 10 and 100 steps.

Each stand was resampled after trampling to determine changes in cover of each algal species. In addition, the animals which use the algal mat for habitat or attachment space were studied by scraping and collecting small areas of algal mat at Sunset Cliffs. Animals were then sorted from the algae, identified, and counted. The association of animals with algal species was noted in order to predict how removing algae affects the animal communities.

Predisturbance of algal mats. The algal mats at Sunset Cliffs and CNM are subject to a variety of environmental conditions. Wave force, sand abrasion and desiccation during low tides are probably the most important factors which shape the communities. The rock substrate which supports the algal mat appears to be relatively flat; however, small ridges and depressions create a microtopographic "maze." Coarse sand and standing water usually fill the depressions.

Coralline algal holdfasts form a lavender to purple crust over the rock ridges but do not extend into the depressions. These holdfasts give rise to the mat of fronds which includes Corallina spp., Lithothrix aspergillum, and Jania crassa. The mat, which is about 5 cm thick, supports as many as 25 different species of epiphytes (Table B1). Most frequently occurring are Centroceras clavulatum, Ceramium spp., Laurencia sinicola, Cryptopleura corallinara, and Hypnea spp., but others can be locally abundant.

Exposed areas of the algal mat are occasionally denuded by extreme sand abrasion or by damage to the rock substrate by strong surf. Recolonization of these naturally-disturbed areas occurs rapidly in low-lying habitats but is delayed in the more exposed locations until after winter storms have subsided. The colonizing community includes Ulva rigida, Cladophora spp., Chaetomorpha spp., Percursaria dawsonii, and Hildenbrandia spp. Corallines reinvade by vegetative reproduction from the adjacent mat.

The most obvious animal of the algal mat is the sea anemone, Anthopleura elegantissima. It occurs both as clones and as solitary individuals within the depressions of the algal mat. Its presence in the mat does not appear to be dependent upon the dominant coralline algae, but several other animal species do require the type of space and cover provided by the calcified algae. The algal mat traps large quantities of sand which in turn provides habitat for burrowing and tube dwelling animals. Nemerteans, Polychaetes, Sipunculids, Ostracods and Ophiuroids are the principal groups found in the sand. Other species attach to the corallines and use sand grains to add

Table B.1. Coralline epiphyte species occurring at Sunset Cliffs and Cabrillo National Monument, San Diego, California

Dominant Coralline	Epiphyte
Corallina spp.	Centroceras clavulatum
	Ceramium sp.
	Jania tenella
	Acrosorium uncinatum
	Mesophylum conchaetum
	Laurencia pacifica
	Sphacelaria sp.
	Hypnea sp.
	Cryptopleura corallinara
	Lithothrix aspergillum
	Plocamium cartilagineum
	Binghamia californica
	Gigartina intermedia
	Laurencia splendens
	Herposiphonia sp.
	Pterosiphonia dendroidea
	Champia parvula
	Coeloseira compressa
	Colpomenia sinuosa
Lithothrix aspergillum	Centroceras clavulatum
	Acrosorium uncinatum
	Laurencia sinicola
	Gigartina intermedia
	Colpomenia sinuosa
Jania crassa	none

support to their mucus tubes. Among these are Isopods, Amphipods and Polychaetes.

Juvenile Brachyurans (crabs), such as Pachygrapsus crassipes, Pugettia producta and Cancer antennarius, are occasionally found foraging on the algal mat at low tide. Adult P. crassipes normally inhabit only the upper and upper-mid intertidal zone, while the juveniles are restricted to the lower algal-mat-dominated zones. This distributional pattern suggests that the algal mat is a nursery for this crab.

Within the depressions or troughs of the substrate are found additional species of animals. On the bottoms are chitons and on the sides, Gastropods. Pholadidea penita, a burrowing lamellibranch, is frequently found within burrows in the rocks. Septifer bifurcatas, Pseudochama exogyra, and Mytilus californianus are occasionally attached to the bottoms and sides of exposed troughs.

Comparing the importance of the animal inhabitants, Amphipods are easily the most numerous; Polychaetes appear to have the greatest biomass; and Molluscs have the most species (22). All species found are listed in Table B 2.

Table B 2. Animal species occurring on the algal mat at Sunset Cliffs and Cabrillo National Monument, San Diego.

Phylum	Species
Coelenterata	Anthopleura elegantissima
Nemertea	Lineus vegetus Carcinonemertes epialti Nemertopsis gracilus
Annelida	Platynereis bicanaliculata; Laeospira borealis: Schistocomus hiltoni; Polychaete A; Polychaete B
Sipunculoidea	Dendrostomum sp.
Arthropoda	Ostracod A; Paranthura elegans; Isopod A; Elasmopus sp.; Hyale sp.; Amphipod (3 species) Pachygrapsus crassipes (juvenile); Pugettia producta (juvenile); Cancer antennarius (juvenile); Pagurus samuelis; Lysmata californica; Spirontocaris sp.
Mollusca	Mopalia muscosa; Nuttallina fluxa; Cyanoplax hartwegii; Septifer bifurcatus; Mytilus californianus; Pseudochama exogyra; Pholadidea penita; Acmaea scabra, Conus californicus; Lacuna unifasciata; Barleeia californica; Vitrinella oldroydi; Haminola virascens; Caecum californicum; Fartulem sp.; Tegula eiseni; Tethys californica; Octopus appollyon
Echinodermata	Ophiuroid (2 species) Strongylocentrotus purpuratus (juvenile)

Response to trampling. The sensitivity of algal species to trampling appears to depend upon the morphological characteristics of their fronds. (Reductions in cover of different communities are shown in Figure B1.

The most delicate of the dominant corallines is Jania crassa. Its largest branches are only 0.25 mm in diameter, and repeated dichotomous branching forms a clump up to 4 cm tall. It is the species which is most sensitive to trampling. Fifty steps is usually sufficient to damage exposed plants. After 100 steps, the holdfast is lost and the bare rock surface is exposed. Recolonization then requires settling of new spores. The greatest cover of Jania crassa occurs under the canopy of Corallina sp. or Phyllospadix scouleri; it occurs without an overstory mainly in semi-protected areas. Algal mat areas dominated by Jania crassa are the lowest in species diversity. Neither epiphytes or animals were ever found in close association with Jania crassa. In part this may be explained by its understory position, but the surface characteristics of the fronds must also be important in excluding other species.

Although the Jania crassa canopy is readily denuded, the loss in habitat for other species is relatively low.

Corallina species are the dominant corallines at CNM. Both the central stipe and lateral branches are made up of alternating rigid and flexible sections which enable the plant to move with the waves and other physical forces, such as trampling. After 50 steps, these plants are not greatly damaged, but a large number of the associated animals are probably crushed. At 150 steps, broken branches are evident, and the thickness of the algal mat is greatly reduced. Between 150 and 400 steps, the Corallina spp. are reduced to a stubby holdfast and then worn away entirely. Damage to Corallina spp. affects a very diverse community of epiphytes and animals.

A third coralline, Lithothrix aspergillum, is dominant at Sunset Cliffs and in some areas of CNM. This species grows from its holdfast in the form of a cylindrical to strap-shaped stipe with cylindrical branches radiating in a congested manner. Its mat is a tangled net-like structure approximately 3-5 cm thick which seems to resist incoming waves. The plants do not sway with the water, as do the Corallina spp. Probably as a result, the light penetration through the Lithothrix aspergillum canopy is low so that few epiphytes are found. Most of the epiphytes that do attach have a wide base or wrap themselves around the cylindrical branches, suggesting that attachment ability restricts other epiphytes from establishing on L. aspergillum. Animals, on the other hand, occur in abundance. All of the smaller species listed in Table B2 are found among the branches and in the fine sand which accumulates at the base of the plants. The community thus contains many animal species, but few plant species.

When the Lithothrix aspergillum mat is trampled, it is first scoured at the surface (50-100 steps) and then is progressively flattened (100-200 steps), until only the basal holdfast remains. Total loss does not occur until trampling intensity reaches 300-400 steps. Although most of the plants and animals are crushed with 200 steps, Gigartina intermedia persists until the rock surface is exposed.

For all of the corallines, the loss of the canopy through trampling brings about the loss of trapped sand within the algal mat. Hence, not

... cover

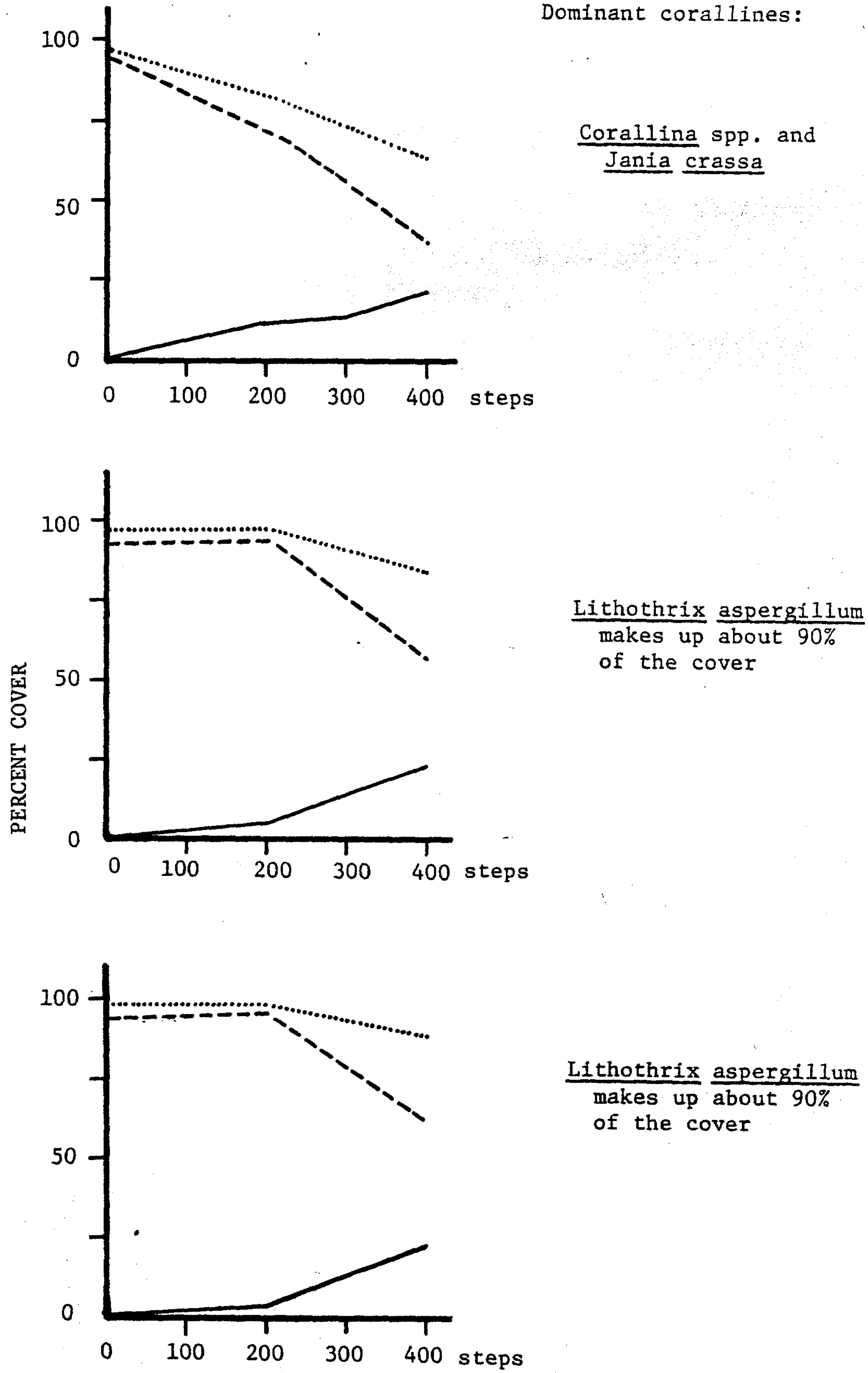


Figure B1. Change in algal cover at Sunset Cliffs with increasing trampling intensity.

······ Total algal cover
---- Total coralline cover
—— Coralline holfast cover

only are attached species lost with their algal substrates, but so are the borrowing forms within the trapped sand. The only survivors are species attached to the depressions or troughs.

Damage to the algal mat community is greatest when hot dry weather coincides with daytime low tides. The corallines become desiccated and brittle and more susceptible to trampling.

Recovery experiments are still in progress, but results obtained thus far suggest that a period of 1-2 years is required for complete recovery of the algal mat community. Repeated damage would, of course, extend the recovery period.

Conclusions.

1. The algal mat at CNM is dominated by coralline algae which support about 25 species of epiphytic algae and numerous species of attached animals.

2. The algal canopy traps sand which in turn provides habitat for burrowing animals.

3. Trampling damages the communities both through direct loss of algal fronds and resulting loss of trapped sand.

4. Sensitivity of algal species to trampling appears to depend upon the morphological characteristics of their fronds.

5. *Jania crassa* is most sensitive; it has delicate branches. However, few other species depend on *J. crassa* for attachment or habitat, so the community has low species diversity. Only 50 footsteps are required to cause significant declines in *J. crassa* cover. Total loss occurs with 100 steps. Regrowth is possible if the holdfasts remain, but with total loss of the plants, the longer process of recolonization by spores is necessary for recovery.

6. *Corallina* species, which are dominant at CNM are slightly less sensitive to trampling than *Jania crassa*. Damage to branches and animals begins with 50 steps. After 150 steps, broken branches are evident and mat thickness is greatly reduced. Between 150 and 400 steps, the mat is reduced to a stubby holdfast and then worn away entirely. Damage to *Corallina* species affects a very diverse community of epiphytes and animals.

7. *Lithothrix aspergillum*, the most common coralline at Sunset Cliffs, is present but not abundant at CNM. It is the most resistant coralline and becomes flattened at 100-200 steps. Total loss does not occur until trampling intensity reaches 300-400 steps. The species harbors few epiphytes, but many animals occur within the mat and its trapped sand.

8. Damage to algae is greater when hot dry weather has desiccated the fronds and made them brittle.

9. Recovery of algal mats probably requires 1-2 years in the absence of continued disturbance, and longer with repeated trampling.

B 2. Effects of rock turning on the under-rock community of CNM (a summary of the study by Robert Shaver, Jr.)

The experiments with rock turning were carried out over a 16-week period beginning July 3-4, 1977, at CNM. Methods of study had previously been worked out in a similar experimental study at Sunset Cliffs in March, 1977. At each location, 15 rocks of similar size and shape (approximately 50 cm diameter) were chosen within an area of uniform elevation to standardize tidal inundation, and with similar algal and invertebrate species present. A map with drawings of each rock was used for relocation throughout the study. Rocks were then randomly assigned to control status (no disturbance) and the following four treatments: 2-week, 4-week, 8-week, and 16-week exposure periods. The under-rock community of each rock was censused at the initiation of the study by counting individuals in four 5 x 10 cm quadrats placed randomly on each upturned rock. Control rocks were then returned to their normal position, and treatment rocks were left upturned for the different periods. All under-rock communities were censused again at 2, 4, 8, and 16 weeks.

The under-rock community has representatives from several phyla, including Arthropoda (barnacles, isopods, amphipods, and decapods), Mullusca (the tube-building *Serpulorbis* is especially abundant), Porifera (sponges), Ectoprocta (bryozoans), and Polychaeta. The two polychaetes, *Spirorbis* spp. and *Phragmatopoma californica*, were the most abundant animals in the community, with *Spirorbis* dominant. Communities at Sunset Cliffs were similar to those at CNM.

Responses to rock turning (exposure). The general patterns of change are indicated by comparing the total density of all species and the numbers of species found under control and treatment conditions.

Total density on control rocks was similar for all 16 weeks of the study (Figure B2). Rocks upturned for two weeks showed no difference from controls or from their initial census. However, sharp declines in density resulted after four or more weeks of exposure. Since *Spirorbis* spp. are the numerical dominants in the community, their declines (Figure B3) are similar to those of total density in the previous figure. Declines are noted as number of visible individuals, and disappearance is not necessarily due to mortality. Smothering by invading algae makes it impossible to see the animals, and while they may not die immediately from exposure, their eventual death is highly likely. Microscopic examination of each individual would be required to assess death in the field. In general, then, between two and four weeks of exposure are required to produce significant changes in densities of all animals considered together. The pattern of significant decline after four weeks exposure (Figures B2-B3) was seen in all but two groups of animals. One species, *Phragmatopoma californica* (Figure B4) was less affected and did not show a decline until 16 weeks of exposure. Sponges (Figure B 5), in contrast, were most sensitive and declined significantly after two weeks exposure.

Numbers of species declined rapidly after two weeks in all treatments (Table B3). After two weeks exposure, the average number of species present declined from 18 to 9 on the two-week exposure rocks

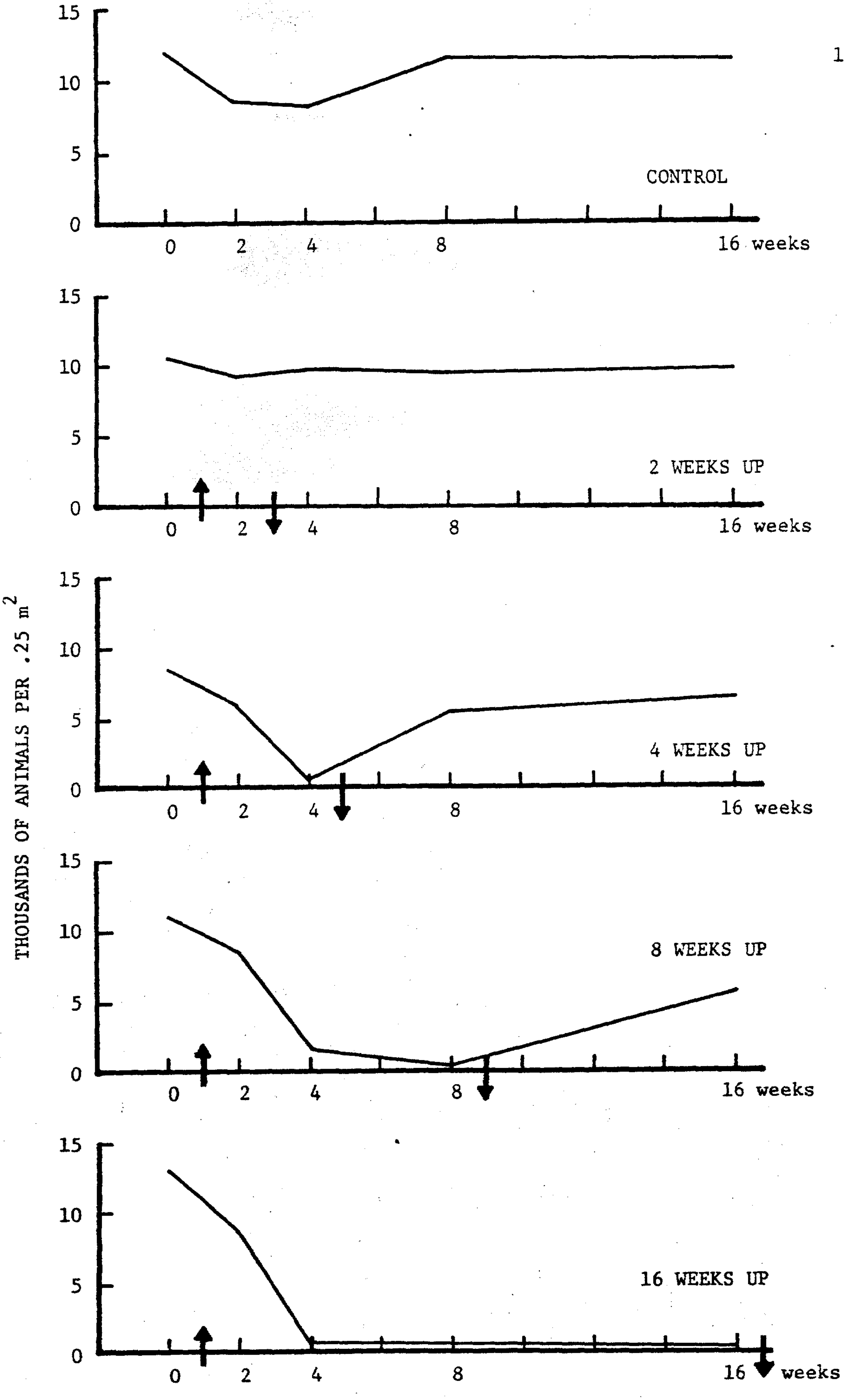


Figure B2. Average density of all species under Control and Turned-Up treatments. Arrows indicate when rocks were turned up and back down.

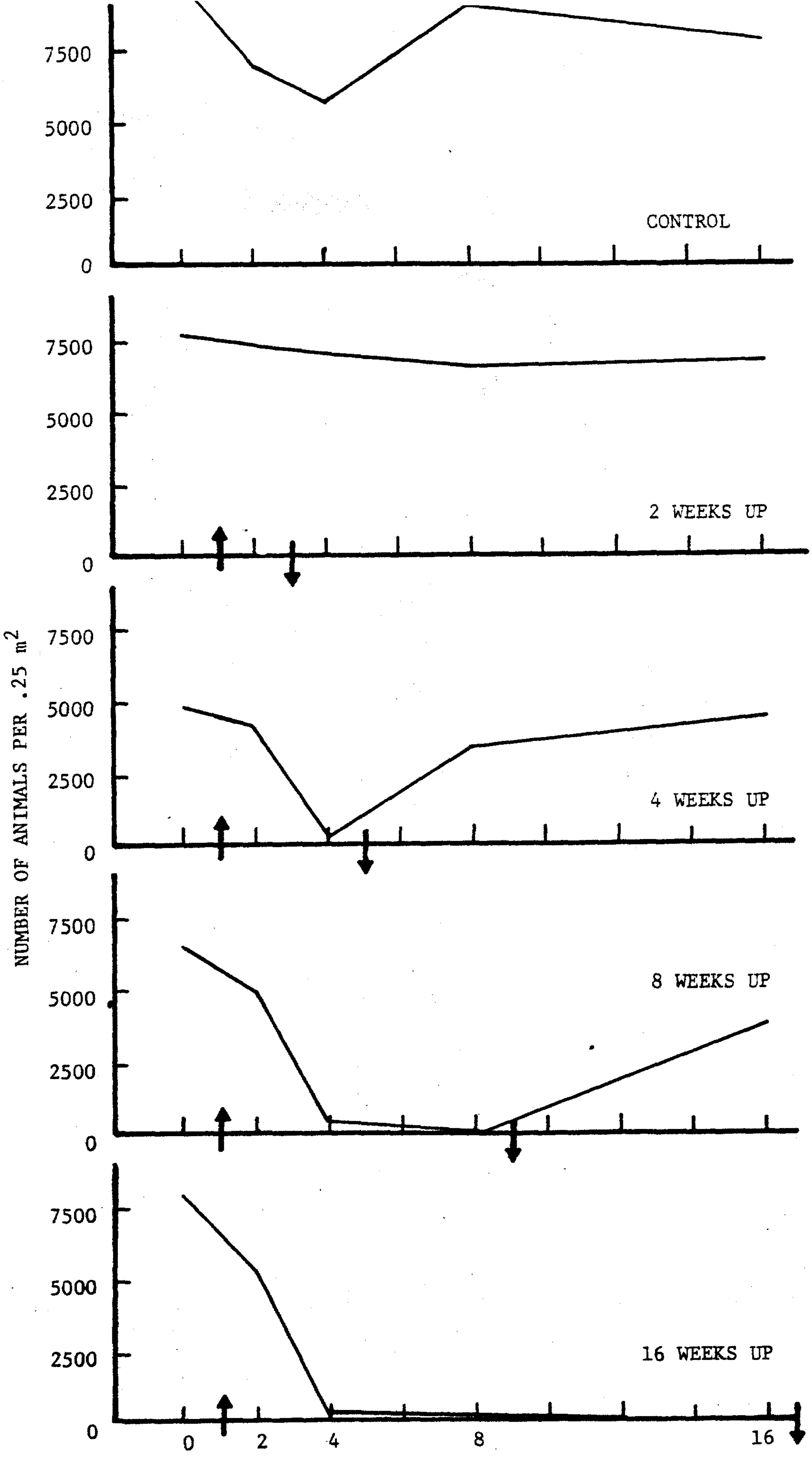


Figure B3. Average density of Spirorbis spp.

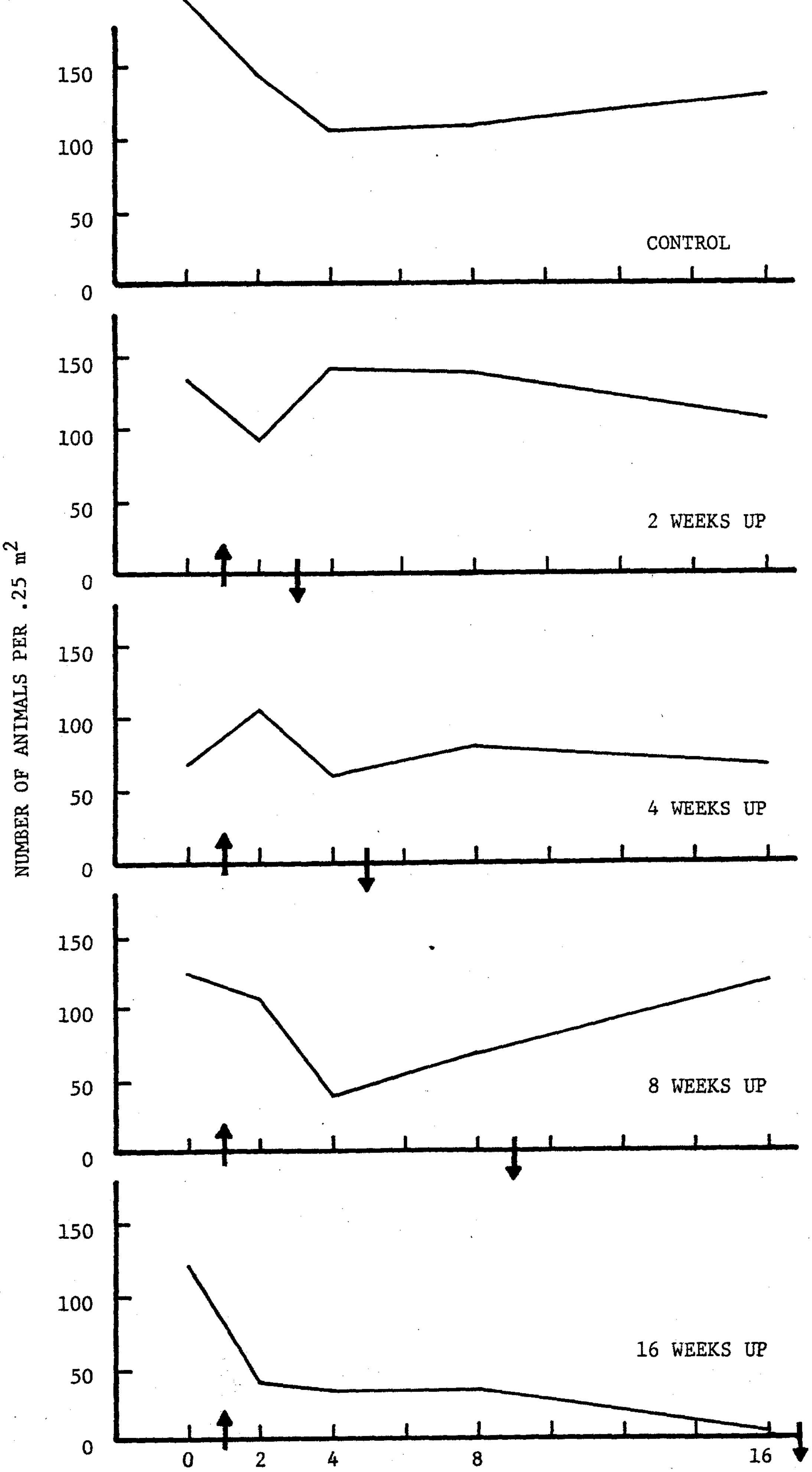


Figure B4. Average density of Phragmatopoma californica.

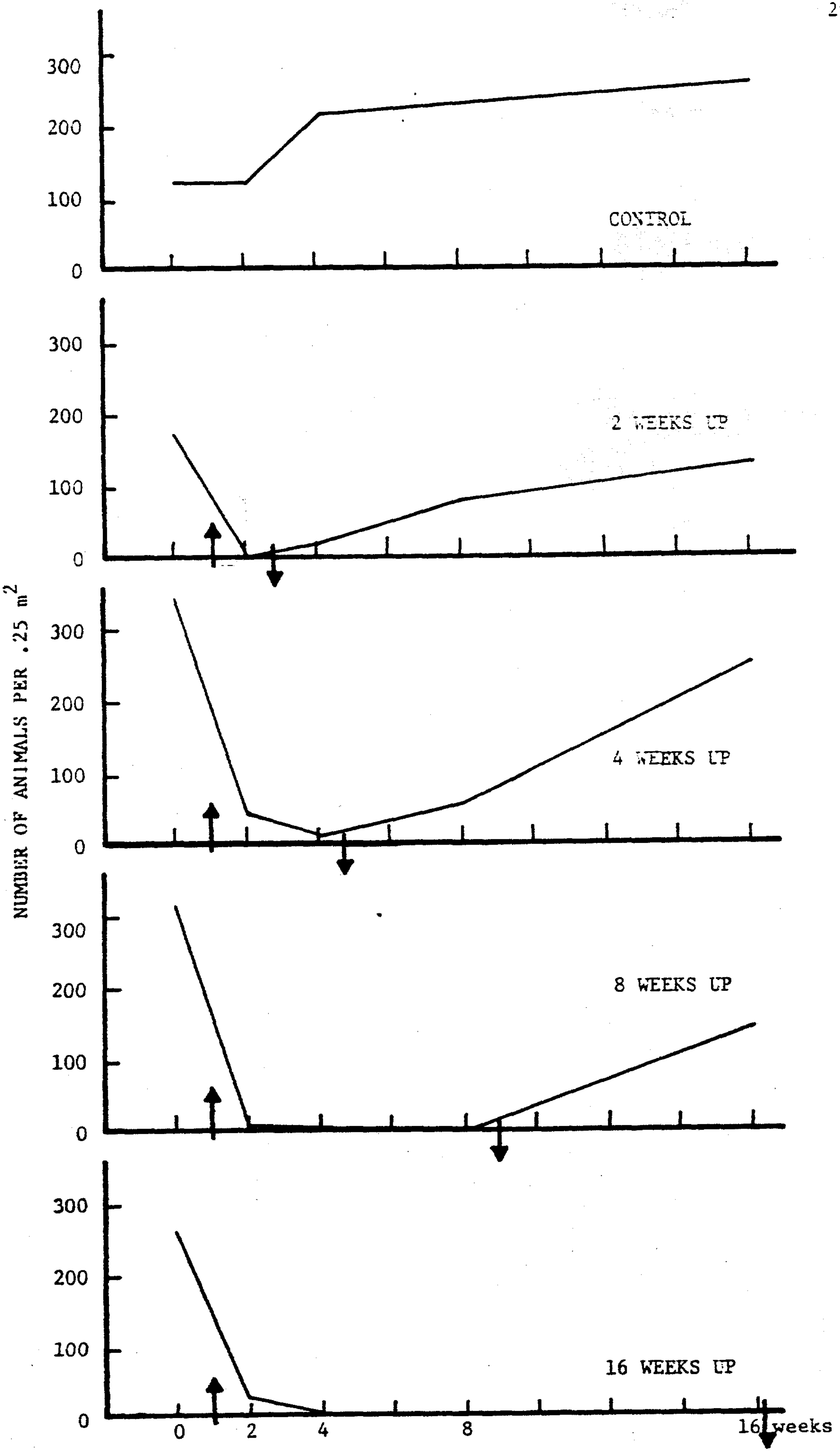


Figure B5. Average density of Porifera (sponges).

and similar numbers on the 4, 8, and 16-week rocks. After four weeks exposure, 3-4 species remained; after 8 weeks, *Phragmatopoma californica* and rare mobile species remained; and after 16 weeks only *Phragmatopoma californica* was present. In all cases, the most persistent species were *Phragmatopoma californica* and *Serpulorbis squamigerus*.

Table B3. Average number of species found at each census date. ↑ indicates date when rock was upturned; ↓ indicates date when rock was returned to its normal position. Numbers of species present while rocks were upturned are underlined for emphasis.

	Census Date				
Period of exposure	0 weeks	2 weeks	4 weeks	8 weeks	16 weeks
0 (control)	13	13	15	14	16
2 weeks	18	↑ *9* ↓	13	11	13
4 weeks	14	↑ *8*	*4* ↓	11	15
8 weeks	14	↑ *7*	*4*	*2* ↓	11
16 weeks	13	↑ *8*	*3*	*1*	*1* ↓

Algal colonization occurred during the period of exposure (Table B4). A green turf dominated by *Ulva* spp. became conspicuous after four weeks exposure which coincided with the sharp decline of animal densities. The colonization of algae may have affected the survival of the animals by interfering with feeding. Sponges, however, died before algal cover was high, and their mortality was probably due to desiccation, predation, or factors other than smothering by algae.

Table B4. Average percent cover of greens on upturned surfaces of rock. ↑ indicates date when rock was upturned; ↓ indicates date when rock was returned to its normal position.

	Census Date			
Period of Exposure	2 weeks	4 weeks	8 weeks	16 weeks
2 weeks	↑ 33.3 ↓			
4 weeks	↑ 29.3	98.0 ↓		
8 weeks	↑ 7.0	67.7	63.0 ↓	
16 weeks	↑ 6.3	86.3	100.0	71.3 ↓

Recovery after return to normal position. Most species showed some recovery during the census time following each exposure treatment. Total density began to return to pre-disturbance levels after 4-8 weeks recovery time, However, complete recovery did not occur by the end of the study. Similar patterns were seen for most species which were examined individually. However, Phragmatopoma californica regrowth exceeded its pre-disturbance density on some rocks. This is not surprising since the species is commonly found in very exposed habitats. Even the sponges, which were sensitive to exposure, showed good recovery after about 6 weeks.

Numbers of species likewise showed rapid recovery (Table B3). The third treatment had only two species present at the end of the 8 week exposure; however, 11 species were found 8 weeks later after the rocks had been returned to their normal position.

Conclusions.

1. Spirorbis is the numerical dominant of under-rock communities at both CNM and Sunset Cliffs.

2. Effects of rock turning are significant after 4 weeks exposure for most species but after two weeks for sponges. Sponges are considered the most sensitive to exposure.

3. A green algal mat (predominantly Ulva spp.) readily invades upturned rocks, with significant densities achieved after four weeks exposure.

4. Recovery of Spirorbis is good once rocks are returned to their original position. Similarly, other species reinvade the habitat after the proper environmental conditions are restored.

5. Rapid recovery suggests that the under-rock species are well adapted to disturbances such as desiccation, battering, and predation. They recolonize rapidly by showing good recruitment on unexploited space. Similar recruitment was not seen on the control rocks where space was not available.

6. The under-rock communities studied show only short-term effects due to rock turning. However, several considerations are important in determining whether rock turning is an undesirable occurrence in the intertidal zone. First, there is obviously some "cost" to the organisms present, since some mortality must occur and recolonization requires recruitment from adjacent habitats. Recolonization here was rapid, perhaps in part due to the fact that only 15 of several thousand rocks were disturbed. Ample sources of offspring were available from nearby rocks. More extensive disturbance would presumably slow the rate of recovery, once offspring were rarer.

Secondly, the study included only animals which attach to rocks. Other members of the under-rock community which are more mobile were not considered. Hence, no predications can be made concerning the effects of rock turning on species such as brittle stars, starfish, etc. Since most of the echinoderms have the ability to regenerate lost limbs or damaged parts, the effects on their populations would probably mostly be in reducing the energy put into reproduction.

B3. Effects of disturbance on selected species (a summary of the work by M. Curtis)

From the examination of abundances of animals in the resource inventory data of heavily and lightly used areas, we hypothesized that limpets (Acmaea spp., recently changed to Collisella), barnacles (Chthamalus fissus), and Phragmatopoma californica were sensitive to public use. To determine if this was the case, we designed several experiments at Sunset Cliffs to test the effects of various kinds of disturbances on individual species. The experiments were: 1) effects of removing limpets from their substrate; 2) trampling barnacles, and 3) damaging Phragmatopoma colonies. Our study of limpets was the most extensive. To compare limpet populations in disturbed vs. less disturbed conditions we examined size distributions of three species at Sunset Cliffs, a heavily used beach, and at CNM, where collecting has been restricted. In addition, we attempted to determine if limpets would respond to disturbances of the algal mat (caused by trampling, as in Lopez' study) by artificially scraping the algae, adding limpets, and examining their survival.

Response of limpets to disturbance. Two species, Acmaea scabra and A. digitalis, occur in the upper intertidal zone and are usually available for examination and removal by the public. A. scabra is easier to remove than A. digitalis, which secretes a membrane between its shell and the substrate.

The least damaging experiment performed was the jiggling of limpet shells, simulating an unsuccessful attempt to remove the shells from their substrate. Survival of A. scabra was 100%, but A. digitalis experienced mortality, and survival was 88%. Presumably, the disruption of its mucus seal led to death.

Response of limpets to complete removal from rocks also differed with species, but here A. scabra had lower survival (Table B 5).

Table B 5. Response of two limpets to removal from cliffs. All individuals were placed upright on rocks near their original position. Data are percent surviving after correcting for losses under controlled conditions.

	Acmaea scabra		Acmaea digitalis	
	Ave. survival	range	Ave. survival	range
Survival:				
After 1 day	62.0%	11-100%	69.0%	40-86%
After 1 week	27.0%	6-53%	62.0%	49-72%

Some mortality was observed in controls, but in all cases, survival following removal was lower than when not disturbed. Survival with the removal disturbance may seem high, but it should be noted that removed limpets were carefully placed upright on rocks near their original location. This is probably rarely true with public disturbance. When limpets are pried from rocks and dropped carelessly, only about 30% land in an upright position. Since limpets cannot right themselves, survival when landing upside--

down is zero. Multiplying the survival rates following reattachment (Table B3) times 30% (the probability of landing upright), gives likely survival rates of 7.6% for A. scabra and 19% for A. digitalis when pried off rocks by the public. We conclude that disturbance of limpets by prying and removing them from cliffs will result in high mortality.

Circumstantial evidence for effects of public disturbance was found by examining size distributions of three limpets at Sunset Cliffs (heavy use) in comparison with CNM. The limpets compared were Acmaea scabra (Figure B6), A. digitalis (Figure B7), and Lottia gigantea (Figure B8). In addition, densities were assessed for the first two species, but Lottia gigantea was too rare at Sunset Cliffs to be sampled adequately. Size distributions are presented in Figures B6 - B8, and average sizes and densities are given in Table B6.

Table B6. Average size (shell length) and density (number per 25 x 50 cm quadrat) of limpets at Sunset Cliffs (SC) and Cabrillo National Monument (CNM). Significant differences are indicated with an asterisk. Data were taken in July and August, 1977.

	Acmaea scabra			A. digitalis			Lottia gigantea		
	SC		CNM	SC		CNM	SC		CNM
Average size (mm)	8.61	*	7.08	9.19	*	12.45	30.61	*	50.26
Average density	18.0		22.4	2.3	*	16.4			

Acmaea scabra is the smallest limpet and the size data show slightly larger individuals at Sunset Cliffs. Densities, however, are similar at both beaches, suggesting that this species is little affected by differences between the two beaches. Even though the species is easier to pry from its substrate, it may be a less attractive target because of its small size.

In contrast, A. digitalis and Lottia gigantea attain larger sizes at CNM. The owl limpet (Lottia gigantea) is especially large at CNM. In addition, both species are more abundant at CNM than at Sunset Cliffs. The results of the removal experiments suggest that this difference could be brought about by public disturbances, which would most commonly affect the larger individuals. Lottia gigantea is fished for human consumption, and since collecting is more restricted at CNM, this practice would be rarer at CNM.

Lastly, the response of limpets to artificially cleared substrates was examined in order to determine if the animals would take advantage of areas which might be denuded by public trampling. The experiments were not extensive, but observations of scraped plots continued for several months. A few limpets settled naturally but losses (mortality or emigration) were high. Limpets placed artificially in the scraped areas remained, on the average, less than a month. This limited response to clearing may be due in part to the small size of the cleared areas (each 10 x 10 cm), since other studies have lead to significant natural recruitment of limpets

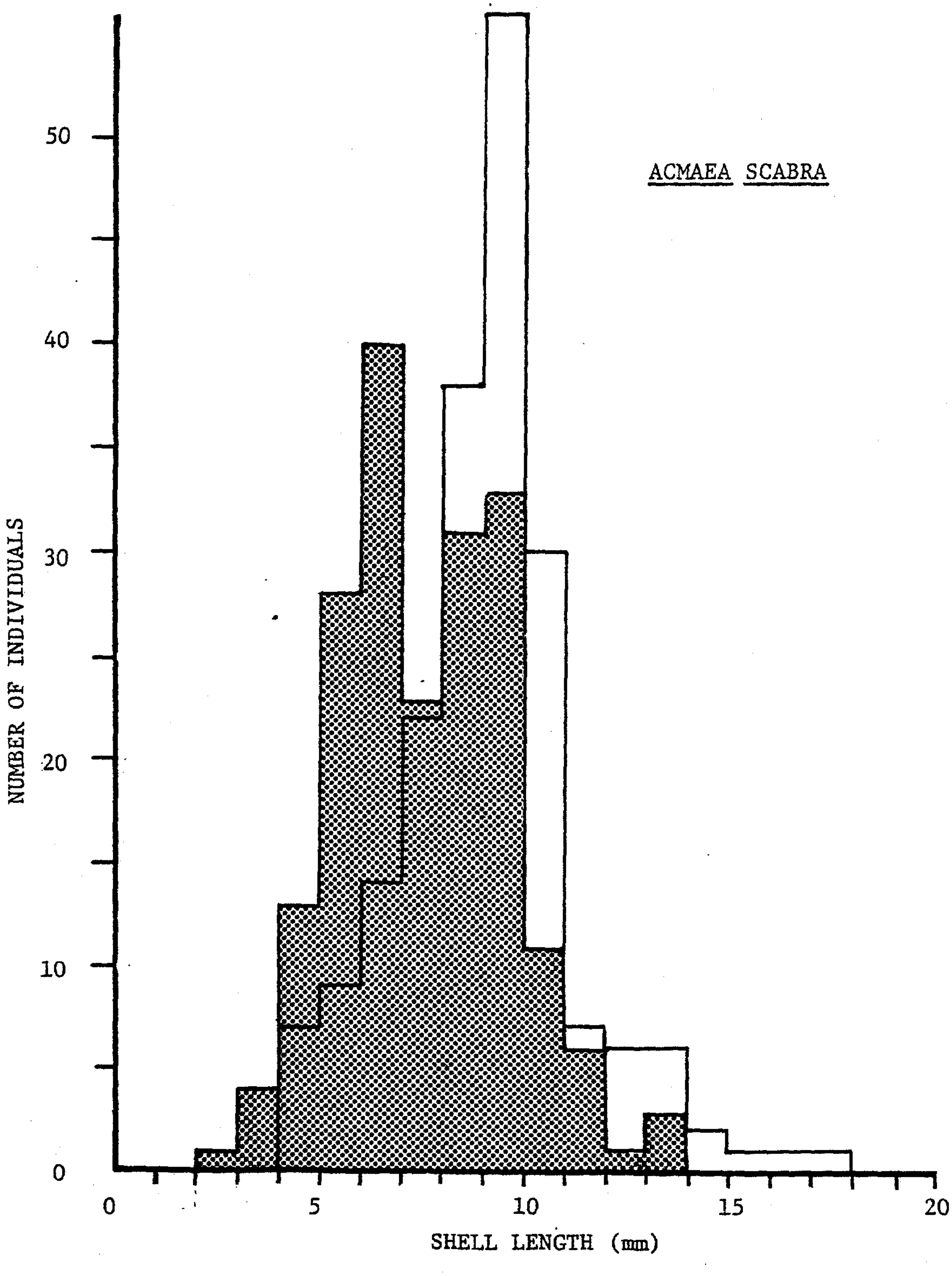


Figure B6. Comparison of the sizes of Acmaea scabra at Sunset Cliffs (clear bars) and Cabrillo National Monument (stippled).

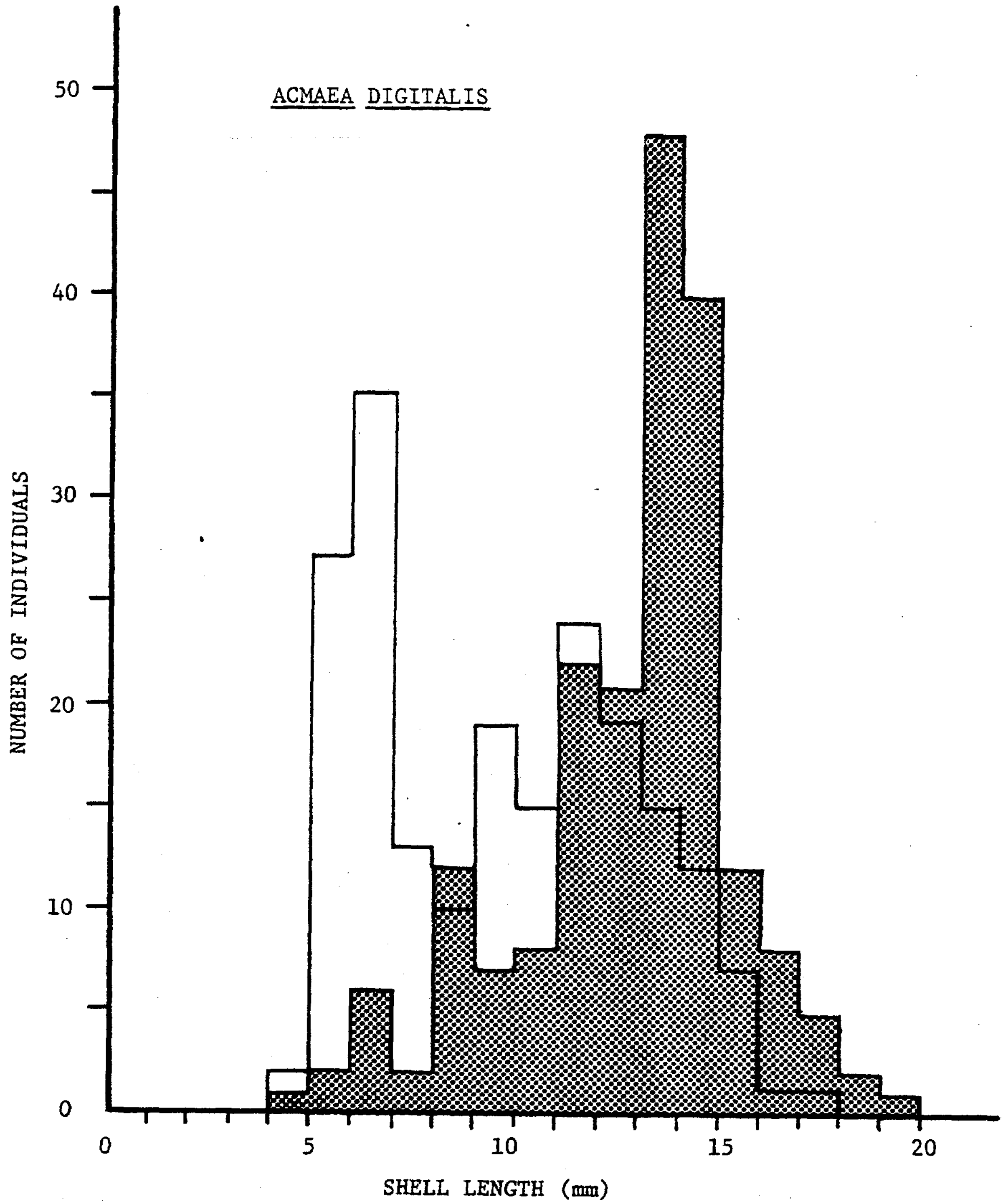


Figure B7. Comparison of the sizes of <u>Acmaea digitalis</u> at Sunset Cliffs (clear bars) and Cabrillo National Monument (stippled).

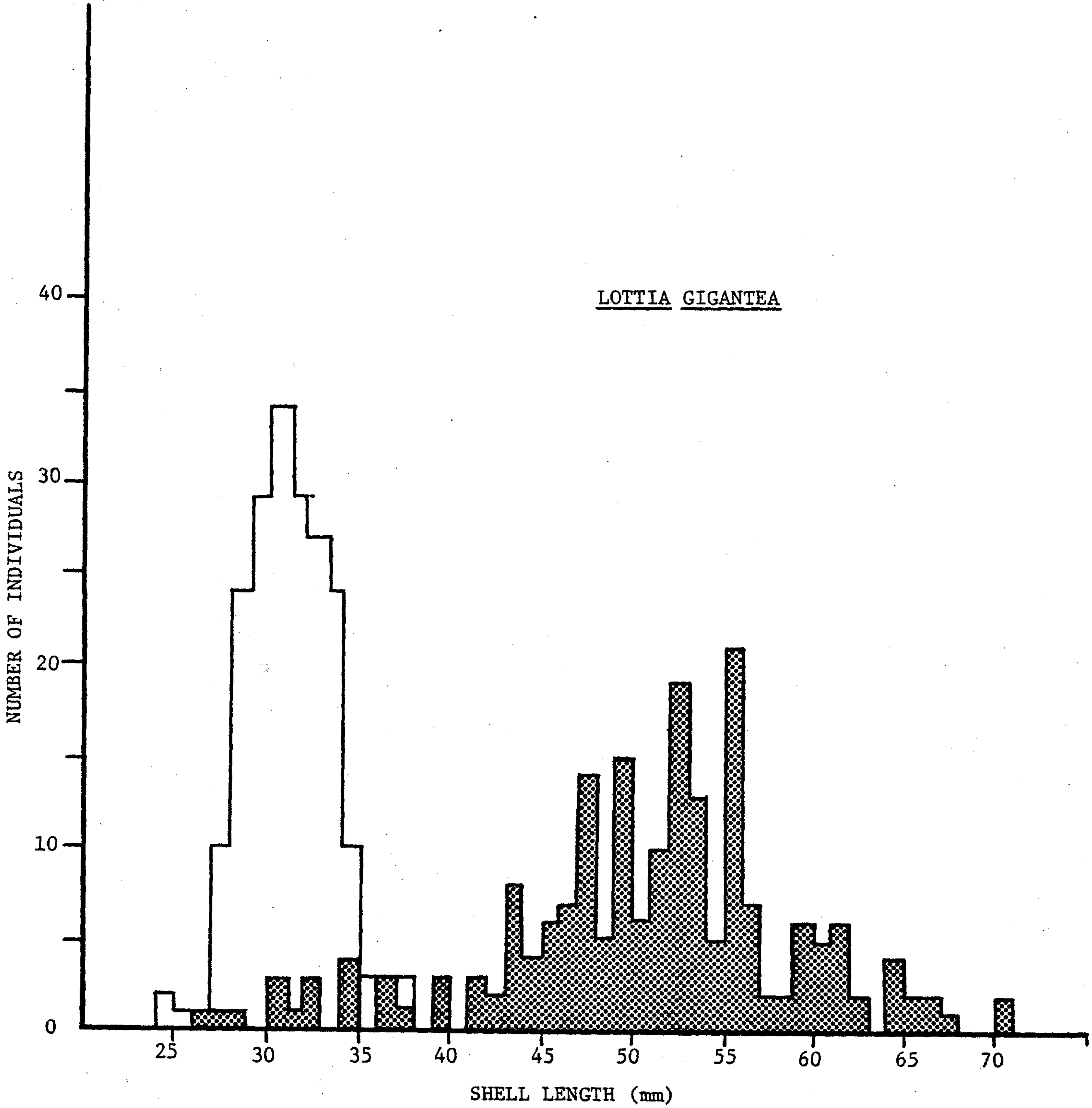


Figure B8. A comparison of the sizes of Lottia gigantea at Sunset Cliffs (clear bars) and Cabrillo National Monument (stippled).

...s. Growth

following algal removal. Rocks cleared by Sue Emerson at False Point in 1973 now have large populations of limpets, as well as several chitons, where an algal turf of Lithothrix used to dominate the substrate. Limpet utilization of cleared substrates may be partly dependent on the size of clearing.

Response of barnacles to trampling. The buckshot barnacle, *Chthamalus fissus*, is very abundant in the upper intertidal area where public trampling is frequent. Barnacle-covered rocks offer good footage in an otherwise slippery substrate, and are sought out by at least the more experienced visitors for stepping stones.

Experiments to assess the impact of trampling were carried out in early summer and again in November 1977. Results differed, with only the early summer experiment showing significant effects due to trampling. This suggests that sensitivity to trampling is seasonal. Three trampling treatments were established to determine the level of disturbance required to result in damage (mortality) (Table B7).

Table B7. Response of *Chthamalus fissus* to three levels of trampling in spring 1977. The number of survivors was censused after 2 days, 2 weeks, and 1 month. Data are average number per 10 x 10 cm quadrats.

	Before trampling	Day 1	Day 14	Day 30	% survival after 2 weeks
Control	393.3	396.6	360.0	366.7	91.5
10 steps	301.7	301.7	301.7	295.0	100.0
100 steps	131.7	108.3	95.0	96.7	72.1
1,000 steps	275.0	200.0	180.0	168.3	65.4

Noticeable effects appeared with the 100-step treatment, and there was little difference in mortality between the 100- and 1000-step treatments.

We conclude from the work with barnacles that mortality due to public use will be seasonal and that significant mortality could result from a single day's use of CNM, especially for those rocks nearest the access where public use is concentrated. In areas where public use is less frequent or where other more desirable footage is available, we expect that differences in mortality due to trampling would not be measurable, due to the high variability of this species' density in the intertidal zone. Barnacles can tolerate light trampling, but not persistent trampling. The mortality levels presented here are not absolute, since they represent results of a single student wearing tennis shoes. Higher mortality would be expected with heavier individuals and with rougher or sandier soles.

Response of Phragmatopoma californica to physical damage. Growth rates of colonies of the sand castle worm (*Phragmatopoma californica*) were monitored for five months under control and disturbed conditions. Growth was assessed by measuring the extension of colonies along the rock substrate (growth in width) and outward (growth in height). Disturbance was accomplished by carefully removing five 3 x 5 cm sections of colonies at Sunset Cliffs. Growth and recovery were then measured from reference points.

The sand castle worm is obviously vulnerable to disturbance, since colonies are readily broken, even with light tapping. To recover from disturbance, the species must recruit new offspring, as growth by budding does not occur. In this experiment, regrowth was at least as rapid as normal growth (Table B8).

Table B8. Growth of _Phragmatopoma californica_ with and without disturbance. Data are cm of increase per month in width and height of colonies at Sunset Cliffs, averaged for up to five months of study during June-December 1977.

	Average	Range
Control		
Growth in width	1.07	0.08-2.06
Growth in height	2.04	0.78-2.74
Disturbed		
Growth in width	2.60	(Colony destroyed by wave action after two months.)
Growth in height	2.13	

However, it is possible that the regrown tubes are more fragile, since the disturbed colony was subsequently destroyed by wave action. Or, the presence of artificially created holes in a solid colony may increase susceptibility of colonies to wave action. This appears to be true when crabs perforate the colonies, as observed at Sunset Cliffs.

Our conclusion is that physical disturbance is very damaging to _Phragmatopoma_ colonies but that the species does have the ability to regrow. Colonies broken by a single footstep (20-30 cm long x 10 or more cm wide) would take several months to regain their former size. More lasting damage would result with frequent disturbance. It is not surprising that robust colonies of this species are limited to the southern tip of CNM where public use is infrequent and where alternate substrates are available for footage.

Conclusions from experiments with individual species.

1. Limpets are detrimentally affected by removal from rocks, with expected survival less than 10% for _Acmaea scabra_ and just under 20% for _A. digitalis_.

2. Sunset Cliffs, which is heavily used by the public, has significantly smaller _A. digitalis_ and _Lottia gigantea_ than CNM. The

difference is greatest for the owl limpet, Lottia gigantea. Sunset Cliffs has a lower density of both limpets. In general, limpet populations are larger and more abundant at CNM.

3. A third limpet, A. scabra, has similar densities at both beaches and slightly larger individuals at Sunset Cliffs. It appears to be little affected by people use, perhaps because its small size makes it a less attractive target for disturbance.

4. The buckshot barnacle, Chthamalus fissus, is susceptible to damage from trampling, and significant mortality occurs with 100-step treatments. Damage appears to be seasonal, with mortality noticeable in spring but not fall.

5. The sand castle worm, Phragmatopoma californica, is readily damaged by physical disturbance. Although regrowth occurs, colonies cannot withstand frequent trampling.

6. In general, the invertebrate species examined here have adaptations important for survival in an environment which has many kinds of natural disturbances (wave force, rock rolling, battering by debris). Most species have planktonic larvae and can recruit from adjacent or even distant populations when local populations are damaged or destroyed. Hence, recolonization and regrowth occur readily. Shell-bearing forms develop resistance to physical damage with age. However, populations do experience lasting effects after repeated disturbances, such as heavy trampling. As larger areas are disturbed, we expect that recovery would take longer. Also, since recruitment is a variable feature of intertidal invertebrates, the timing of recovery is difficult to predict. From the work discussed here, we conclude that the long term effects of disturbance will be lower densities and smaller size of susceptible intertidal invertebrates.

C. Resource Monitoring

Six habitats were sampled in three areas in Spring and in Fall 1976 (see the 1976 report for details), and the same six habitats were sampled in two of the three areas in Spring and Fall, 1977. The habitats are: Cliff Face, Barnacle Rocks, Algal Mat, Pelvetia Rocks, Mytilus Rocks, and Phyllospadix Pools. The three areas for 1976 were called "Low Use," "North Use," and "South Use" (Figure Al), which coincided with visitor patterns during that year when the access was near the parking lot, and when most people stayed in the area south of Grunion Beach. The "Low Use" area was located north of Grunion Beach. A landslide near the parking lot led to the closure of that access and diversion of all visitors to the area north of Grunion Beach where the present access exists. The "Low Use" area then became the heaviest use area, and the former "Use" areas began to receive fewer visitors.

Resampling in 1977 occurred at the former "Low Use" area and at the two areas south of Grunion Beach. Because the biota of the southern areas were similar, we reduced sampling by selecting the six habitats most similar to those at the "Low Use" area from those available in the two southern locations. All habitats except Pelvetia Rocks were resampled in the former "South Use" area; the remaining habitat was sampled in the former "North Use" area.

Sampling methods were identical to the 1976 sample with one improvement--animals were counted within oblong quadrats (5 x 20 cm) instead of square quadrats (10 x 10 cm) to reduce the variance in the sample data. Insofar as possible, we sampled the exact same rocks or areas as in 1976. Three one m^2 sampling frames were placed in each habitat in each area, and three randomly located quadrats were placed to count animals. Percent cover of algae was determined by examining the species present underneath the 100 points in each m^2 sampling frame. One additional frame was used on the algal mat and in Phyllospadix Pools.

Several data comparisons are possible to aid our understanding of community dynamics at CNM. Since the patterns of use were different for 1976 and 1977, we have tried to find evidence of changes in biota which are related to increased use in the current access area and decreased use in the former access area. For ease in discussing these comparisons, the former "Low Use" area will be referred to as the New Access; and the former "North and South Use" areas will be abbreviated as the Old Access (Figure Al). Data for plants and animals will be considered separately. In all cases, only those species which showed statistically significant differences will be discussed. All others may be considered similar from sample to sample within the limitations of the sampling program (i.e., differences may exist, but due to variability in the data, significance was not demonstrated).

1. Plants (data analyzed by J. Lopez). Differences between the Old Access and New Access will first be compared for the most recent sample (Fall 1977); then Fall 1977 data will be compared to the Fall 1976 data; and lastly the 1977 Spring and Fall data at the New Access will be compared (Table Cl).

Several differences in algal cover for the Old and New Access habitats involved the prostrate, tar-like Ralfsia sp. For the Cliff Face, Barnacle

Table C1. Statistically significant differences in plant cover for several data comparisons.

1. Fall 1977 data--comparisons of Old and New Access habitats

Habitat and Species	Ave. % Cover in Old Access Area (formerly "North & South Use")	Ave. % Cover in New Access Area (formerly "Low Use")
Cliff Face: *Ralfsia* sp.	8.3	20.0
Barnacle Rocks: *Ulva rigida*	11.7	0
Barnacle Rocks: *Ralfsia* sp.	7.7	0
Mytilus Rocks: *Ralfsia* sp.	0	14.3
Algal Mat: combined corallines (mostly *Corallina pinnatifolia* and *Jania crassa*)	58.2	91.8
Phyllospadix Pools: *Phyllospadix scouleri*	74.2	97.2
Phyllospadix Pools: *Melobesia mediocris* (obligate epiphyte on *Phyllospadix scouleri*)	23.2	41.0
Phyllospadix Pools: combined corallines	38.8	11.2
Phyllospadix Pools: understory cover	74.8	51.8

2. Fall Data--comparisons of 1976 and 1977

	1976	1977
New Access, Cliff Face: *Ralfsia* sp.	48.0%	8.3%
Old Access, Algal Mat: *Coeloseira compressa*	13.5	0
Old Access, Algal Mat: *Ceramium* sp.	0	28.0
Old Access, Phyllospadix Pools: *Chondria californica*	10.8	1.8
Old Access, Phyllospadix Pools: *Ulva rigida*	7.2	1.0

3. 1977 Data--comparisons of Spring and Fall at the New Access

	Spring 1977	Fall 1977
Algal Mat: combined corallines	120.2	91.8

Rocks and Mytilus Rock habitats, its cover was significantly higher at the New Access than the Old Access. The same difference was found for Cliff Face in Fall 1976, so that it is doubtful that these differences represent a major response to altered public use.

In the Algal Mat habitat, corallines had higher cover in the New Access area than at the Old Access. This was largely because *Corallina pinnatifolia* had 20.2% cover and *Jania crassa* had 15% cover at the New Access, and *C. pinnatifolia* had 5% cover and *J. crassa* was absent from the Old Access. The cover of corallines at the New Access is not constant, however, and a significant decrease was noted between Spring and Fall, 1977. Since the canopies of different species overlap, the sums of several species can exceed 100%, and the Spring value was 120.2% compared to 91.8% in Fall. Since public use increased between the Spring and Fall samples, some of this decline may be due to trampling, as demonstrated in the experimental study of J. Lopez.

Phyllospadix Pools had several differences in Fall 1977, with the New Access having higher *Phyllospadix scouleri* cover and resulting higher cover of its obligate epiphyte, *Melobesia mediocris*. Possibly also as a result of higher *Phyllospadix* cover, the understory cover was lower at the New Access, and combined corallines were also lower. In Fall of 1976, the cover of *Phyllospadix scouleri* was similar at the New Access (95.8%), but lower at the Old Access (47.5%). Examination of the raw data showed that each Old Access quadrat sampled in 1976 had increased its *Phyllospadix* cover by 1977. This suggests strongly that the Phyllospadix Pools of the Old Access area are responding to decreased visitor use, and that several algal species change their abundance along with *Phyllospadix*: epiphytes increase and understory species decrease.

2. Animals. (data analyzed by M. Curtis). Data for animal densities are compared in the same manner as the plant cover data. Differences between the New and Old Access areas are compared for fall 1977; then the New Access habitats are compared for the fall of 1976 vs. 77 and for spring and fall 1977 (Table C2). Again, responses to changes in people use are sought by looking for consistent patterns in these 3 comparisons.

Mytilus californianus on Mytilus Rocks is the only species which both has greater density at the Old Access in fall 1977 and shows a significant decline at the New Access between fall 1976 and 1977. Since the public use study shows that *Mytilus* is frequently abused, it is quite possible that these differences are related to increased use at the New Access.

Other species which show the reverse pattern of change, i.e. a higher density at the New Access in 1977 and increased density between fall 1976 and 1977 at the New Access are *Acmaea scabra* and *Chthamalus fissus* on the Cliff Face and *Acmaea strigatella* on Pelvetia Rocks. Of these, the *Acmaea* species also increased in density at the New Access between spring and fall 1977. For all three species, it is possible that there is a positive response to increased public use, but the experimental studies should be considered before drawing that conclusion. *Acmaea scabra* was damaged by experimental removal from rocks, but comparisons of density and size frequency at the heavily used Sunset Cliffs beach with the CNM study area suggested that this species is not much affected by public use. Possibly its small size in comparison with other limpets allows it to escape abuse. Hence, a short-term increase in density at the New Access would not be impossible, especially when other grazer competitors showed decreases (*A. strigatella* and *Littorina scutulata*) at the New Access.

The increase of *A. strigatella* on Pelvetia Rocks at the New Access is not easily explained, because this species was not included in experimental studies and its response to disturbance is not known. This species increased between spring and fall 1977 on the Mytilus Rocks also, but it decreased on the Cliff Face between fall 1976 and 1977.

The increase of *Chthamalus fissus* might seem to contradict the results of the trampling experiments. However, since the increase occurred on the Cliff Face habitat, no trampling would have occurred there and no decrease would be expected. The density of *C. fissus* on barnacle rocks, where trampling is frequent, did not show a significant difference between 1976 and 1977. *Balanus glandula*, however, did have a decreased density on Barnacle Rocks between spring and fall 1977, and this may have responded to visitor trampling.

Conclusions. The patterns in plant and animal abundance which appear to be related to changes in public use at CNM are:

1. Possible decline of corallines in the Algal Mat at the New Access where visitor use has increased.

2. Increased cover of *Phyllospadix scouleri* in the Phyllospadix Pools of the Old Access where visitor use has declined. Other species which change as a result of increased *Phyllospadix* cover are its obligate

Table C2. Statistically significant differences in animal densities for several data comparisons. Data are numbers per 5 x 20 cm quadrat.

1. Fall 1977 data--comparisons of Old and New Access habitats

Habitat and Species	Ave. density at Old Access Area	Ave. density at New Access Area
Pelvetia Rocks: Acmaea scabra	40	0
Pelvetia Rocks: A. strigatella	86.6	153.3
Cliff Face: A. scabra	106.7	273.3
Cliff Face: Chthamalus fissus	960.0	2,173.3
Mytilus Rocks: Acmaea limatula	66.6	0
Mytilus Rocks: A. strigatella	133.3	540.0
Mytilus Rocks: Lottia gigantea	0	26.7
Mytilus Rocks: Mytilus californianus	5,313.3	680.0
Mytilus Rocks: Pollicipes polynices	0	346.7

2. Fall data--comparisons of 1976 and 1977

Habitat at New Access Area	1976	1977
Pelvetia Rocks: Phragmatopoma californica	132.2	1,226.7
Pelvetia Rocks: Acmaea strigatella	38.9	153.3
Pelvetia Rocks: Balanus glandula	11.3	2,180.0
Mytilus Rocks: A. strigatella	740.0	540.0
Mytilus Rocks: Mytilus californianus	1,306.7	680.0
Mytilus Rocks: Balanus glandula	660.0	3,753.3
Mytilus Rocks: Chthamalus fissus	4,580.0	12,233.3
Cliff Face: A. scabra	96.7	273.3
Cliff Face: A. strigatella	62.2	20.0
Cliff Face: Chthamalus fissus	394.5	9,194.7

3. New Access Area--comparison of Spring and Fall 1977

	Spring	Fall
Cliff Face: Acmaea scabra	20.0	273.3
Cliff Face: Littorina scutulata	313.3	53.3
Barnacle Rocks: Balanus glandula	133.3	0
Mytilus Rocks: A. strigatella	126.7	540.0
Mytilus Rocks: Balanus glandula	240.0	3,753.3
Phyllospadix Pools: A. palacea	33.3	586.7
Pelvetia Rocks: A. strigatella	46.7	153.3
Pelvetia Rocks: Balanus glandula	6.7	2,180.0

epiphyte Melobesia mediocris, which increases, and its coralline understory species, which decrease.

3. Declines of Mytilus californianus (mussels) on Mytilus Rocks at the New Access, where public use increased and abuses to mussels were documented.

4. Increases of the small limpet Acmaea scabra and the buckshot barnacle Chthamalus fissus on Cliff Faces of the New Access. A. scabra does not appear to be abused by visitors, and C. fissus cannot be trampled in this habitat, so these increases do not contradict the experimental work with these species.

5. Again, as in 1976, the high variability of inventory data on intertidal species limits our ability to demonstrate differences in species where visitor use is known to have changed. The experimental data obtained from trampling, rock turning, and irritation of selected species demonstrate the cause-effect relationships between species abundance and visitor use and provide guidelines for interpreting results from the monitoring data.

6. In general, 1977 appears to have been a "good year" for the settling of invertebrates in the intertidal zone of CNM. Greater responses to public use may be measurable in years where physical conditions are more hostile to intertidal biota.

D. Reconnaissance of the south and east coasts of CNM

A general inventory of the south and east coasts of the Cabrillo intertidal zone was accomplished in December 1977, using aerial photography and ground reconnaissance. Areas were subjectively delineated by J. Zedler and species lists and descriptive notes were recorded by J. Lopez (plants) and R. Shaver (animals). Seven "Areas" were recognized; they are located by Roman numeral and nickname on the map in Figure D1 for cross reference with the following descriptions and photos (Figures D2-D7). In general, the areas differ more in the relative abundance of different habitat types than in species composition.

I. Conglomerate Rock-Small Boulder Site. Located in far north east corner of Cabrillo's coastline. This area has a large gravel substrate in the upper intertidal zone; Pelvetia and Phragmatopoma occur on small boulders; red algal turf occurs on flat rocks, and Phyllospadix and Egregia are abundant in the lower areas. See Figure D2.

Plants: Algal species diversity seems very low. The upper to mid-intertidal area is dominated by Pelvetia fastigiata in the upper area and P. fastigiata and Corallina vancouveriensis in the mid-intertidal area. The lower intertidal area is characterized by a belt of Phyllospadix scouleri with a sparse understory of Corallina vancouveriensis and Chondria nidifica. Rocks in this area are moderately covered by Corallina spp., Gelidium coulteri, Gastroclonium coulteri and Gelidium pusillum. The lowest areas have a Halidrys dioica and Egregia laevigata canopy with Corallina sp. and Gastroclonium sp in the understory.

Animals: Littorina planaxis, Chthamalus fissus, Acmaea scabra and Anthopleura elegantissima are common in the upper intertidal area. Phragmatopoma californica, Cyanoplax hartwegii (with Pelvetia), Acmaea pelta, Pagurus spp., Tetraclita squamosa, Spirorbis, Mitrella carinata and Macron lividus, Membranipora fusca, Serpulorbis squamigerus and Pugettia producta (large with 10 cm wide carapace) were abundant in the lower intertidal areas.

II. Sand with Conglomerate Boulders and Sandstone Boulders. Located south of area I. The upper intertidal area is lacking in algae and animals. Even the rocks are bare of barnacles. Presumably the soft substrate and scouring action of shifting sand are responsible for the abiotic nature of the habitat. Much debris was deposited as drift; erosion was evident in this unstable habitat. Lower areas are similar to areas I and III. See Figure D3.

III. "Egret Inlet." Located midway along the bay side of the Monument. This area had several egrets foraging for food at the time of census. (Fig. D3).

Plants: Upper intertidal rocks were mostly devoid of algae; some Ralfsia sp. and Ulvia rigida plants were present. Small cobbles with Corallina vancouveriensis were moderately covered with drift. Standing water in pools accounted for the occurrence of Phyllospadix scouleri. The lower intertidal vegetation was a mixture of Phyllospadix, Egregia, and Halidrys overstory and Corallina vancouveriensis, Chondria nidifica, and Gastroclonium understory. The lowest level rocks were moderately covered with Centroceras clavulatum on C. vancouveriensis. Species not encountered at areas I-II include Gigartina leptorhynchos, Sargassum muticum, Laurencia pacifica, Rhodymenia californica, Plocamium pacificum,

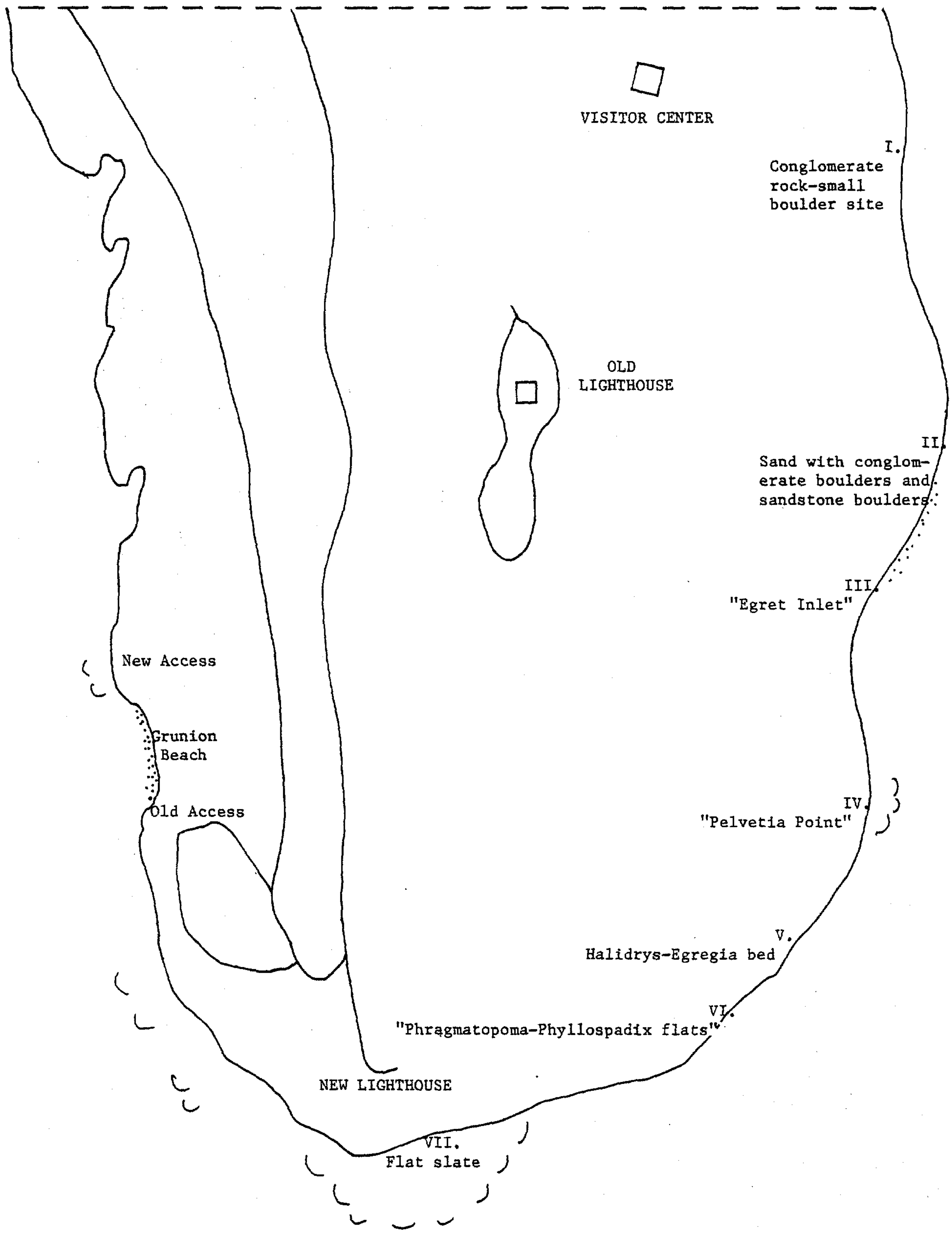


Figure D1. General outline of the CNM coastline. Roman numerals indicate the areas where species lists were made. See Figures D2-D6 for Photographs.

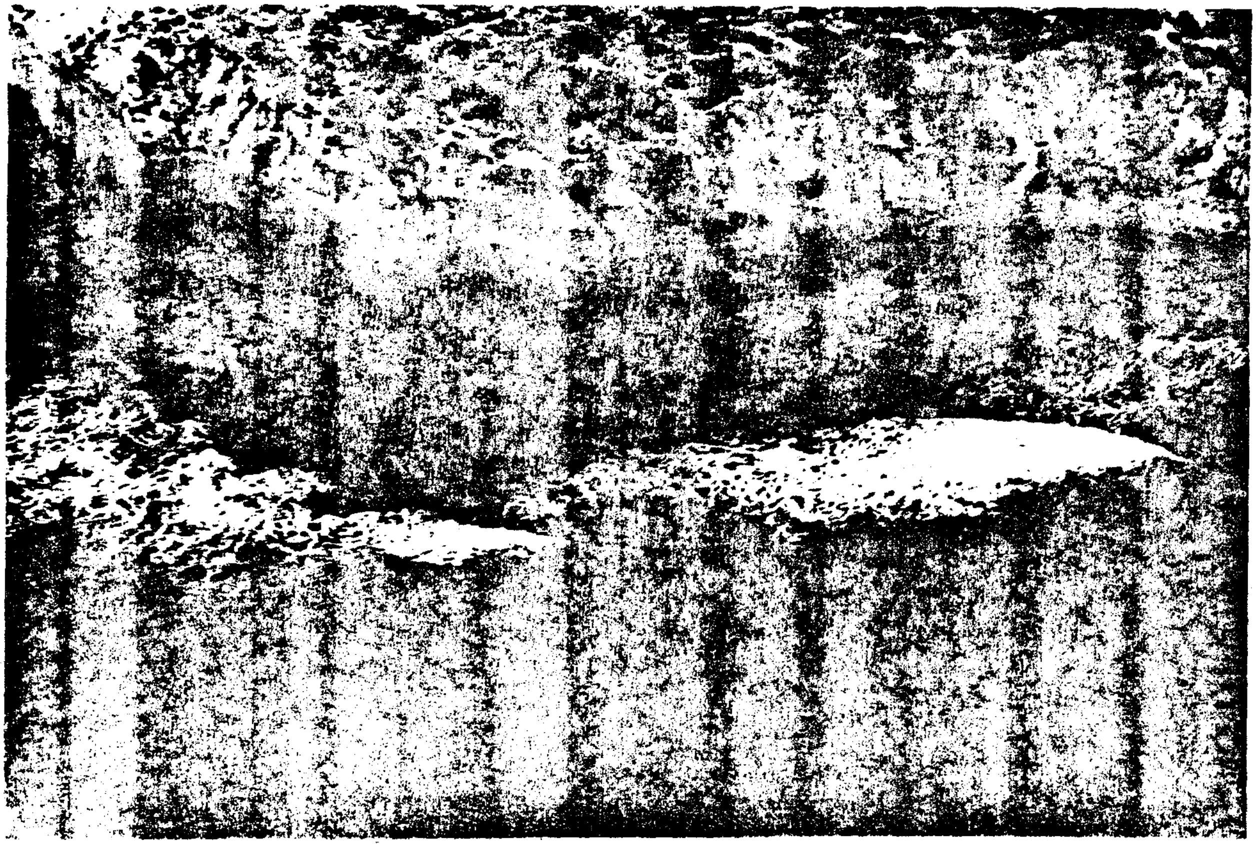


Figure D2. Area I on Figure D1--Conglomerate Rock-Small Boulder Site.

Figure D3. Area II (right) and Area III (left) on Figure D1.
Sand with Conglomerate Boulders and Sandstone Boulders.

Corallina officinalis var. chilensis, Pterocladia capillacea, Laurencia spectabilis, and Macrocystis integrifolia.

Animals: Kelp flies and terrestrial isopods are abundant in the upper intertidal zone. Tegula funebralis is especially abundant and individuals were especially large in the upper intertidal area. Also present were Mytilus californianus Chthamalus fissus, Anthopleura elegantissima, Acmaea limatula, A. strigatella, Phragmatopoma californica, Pagurus (in Olivella shells), Mopalia sp., Stenoplax conspicua, Spirorbis sp., Pugettia producta, Serpulorbis sp, Xestospongia vanilla, and Cnemidocarpa finmarchiensus. The Pugettia producta were both large and abundant. About 50 individuals were found among the Phyllospadix; many had carapaces over 10 cm wide. Also one Cancer crab was found with a 10 cm carapace.

IV. "Pelvetia Point." Large rock outcrop along the southeast part of the monument. A small beach plant community occurs above high tide line.

Plants: Upper to middle intertidal areas are characterized by Pelvetia fastigiata on protruding conglomerate rocks with understory of Lithothamnion sp. and Corallina pinnatifolia or C. vancouveriensis. Some Cryptopleura corallinara and Pterocladia capillacea were present and an occasional Halidrys dioica. Dense stands of Pelvetia also contained an understory of Gelidium coulteri, Laurencia pacifica, Gastroclonium coulteri and Rhodoglossum affine in moderate amounts. Hi lden brandia sp. was conspicuous. The lower intertidal species include Corallina vancouveriensis, C. officinalis var. chilensis, C. pinnatifolia, Pterocladia capillacea, Gelidium arborescens, Crypotpleura corallinara, Egregia and Halidrys. Species diversity was very high.

Animals: In the upper intertidal area, Chthamalus fissus, Anthopleura elegantissima, Acmaea scabra, A. digitalis, A. strigatella, A. limatula, Cyanoplax hartwegii (with Pelvetia) and Pagurus spp. were abundant. With Phragmatopoma californica, Chthamalus fissus and Balanus glandula were found Tetraclita squamosa, Lottia gigantea, Septifer bifurcatus, Pachygrapsus crassipes, Acanthina lugubris, Acmaea paleacea, Pollinices lewisii, Fissurella volcano, Stenoplax conspicua, Acmaea incessa (with Egregia) and A. pelta.

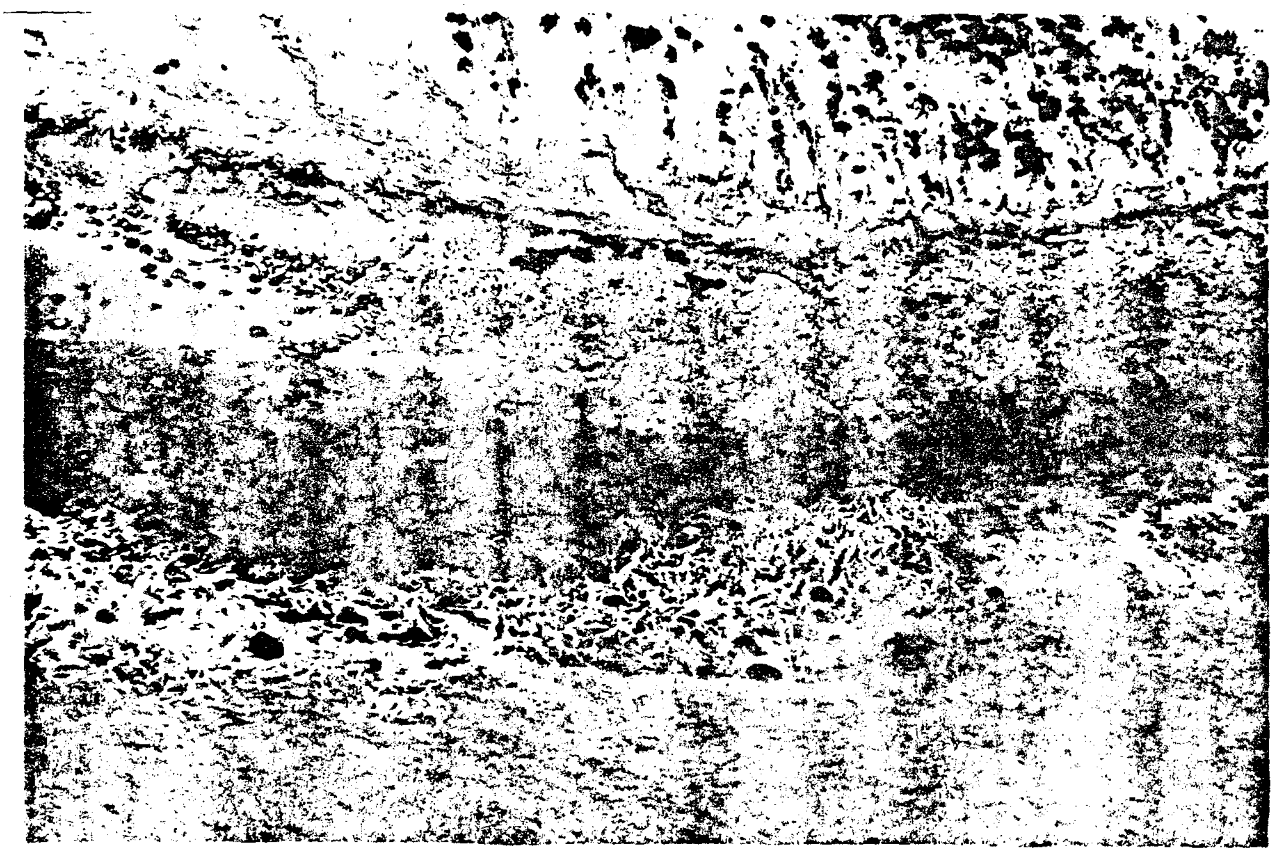
V. Halidrys-Egregia bed. Located just west of area IV. Large brown algae (kelp) were abundant. See Figure D4.

Plants: Dominant algae were Egregia laevigata and Halidrys dioica with an understory of Corallina officinalis var. chilensis, Rhodymenia pacifica, R. californica, Gelidium arborescens, Corallina vancouveriensis, Dictyota flabellata, Bossiella orbigniana and others. The lower intertidal is very much like that of "Pelvetia point" except that the red algae were very robust and more species of reds seemed to be present.

Animals: Littorina planaxis, Chthamalus fissus, Phragmatopoma californica, Serpulorbis squamigerus were conspicuous, with Lepidozona californiensis, Aplysia californica, and Plocamia karykina also present.

Figure D4. Area V of Figure D1. A Halidrys-Egregia bed in the lower intertidal zone.

Figure D5. Area VI of Figure D1. "Phragmatopoma-Phyllospadix flats." Thick colonies of Phragmatopoma are visible on the lower boulders.



VI. "Phragmatopoma-Phyllospadix flats." Located west of area V and east of the flat slate rocks on the point of the peninsula. The upper to mid-intertidal areas have massive colonies of Phragmatopoma. See Figure D5.

Plants: Gelidium coulteri borders the sand castles; also apparent on the rocks are Gelidium pusillum and Rhodoglossum affine. The Phyllospadix area in the lower intertidal zone was basically similar to the previous sites except that Pachydictyon coriacium and a few other species are added.

Animals: Species of Chthamalus and Acmaea dominate the upper intertidal zone; the largest colonies of Phragmatopoma are found in the middle zone along with Anthopleura elegantissima, Acmaea palacea , Serpulorbis squamigerus, Pisaster ochraceus, Haliotus cracherodii, and Pteropurpa sp.

VII. Flat slate. Located south of the new light house. This area is unusual for its flat, solid substrate. See Figure D6.

Plants: The upper intertidal was characterized by microscopic algal films, probably diatoms. Toward the ocean, there are clumps of Corallina spp. Epiphytes on the coral lines include Centroceras, Ulva rigida, Binghamia californica, Lithothrix aspergillum, and Laurencia sinicola. The mid-intertidal is approximately 50-70 meters long and is characterized by a dense coralline algal mat covering 80-95% of the substrate. New species were Corallina polysticha and dense clumps of Lithothrix aspergillum. Taonia lennebacheriae, Sargassum muticum, Dictyota flabellata and Colpomenia sinuosa are evident in the tide pools.

The intertidal areas at the upper spray zone are very different on the east and south coasts compared with the west coast of CNM. The cliffs on the east and south are more readily eroding. Those on the west are more solid sandstone (relatively solid, that is.) See Figure D7 for an example of the sandstone cliffs (taken north of the "New Access."

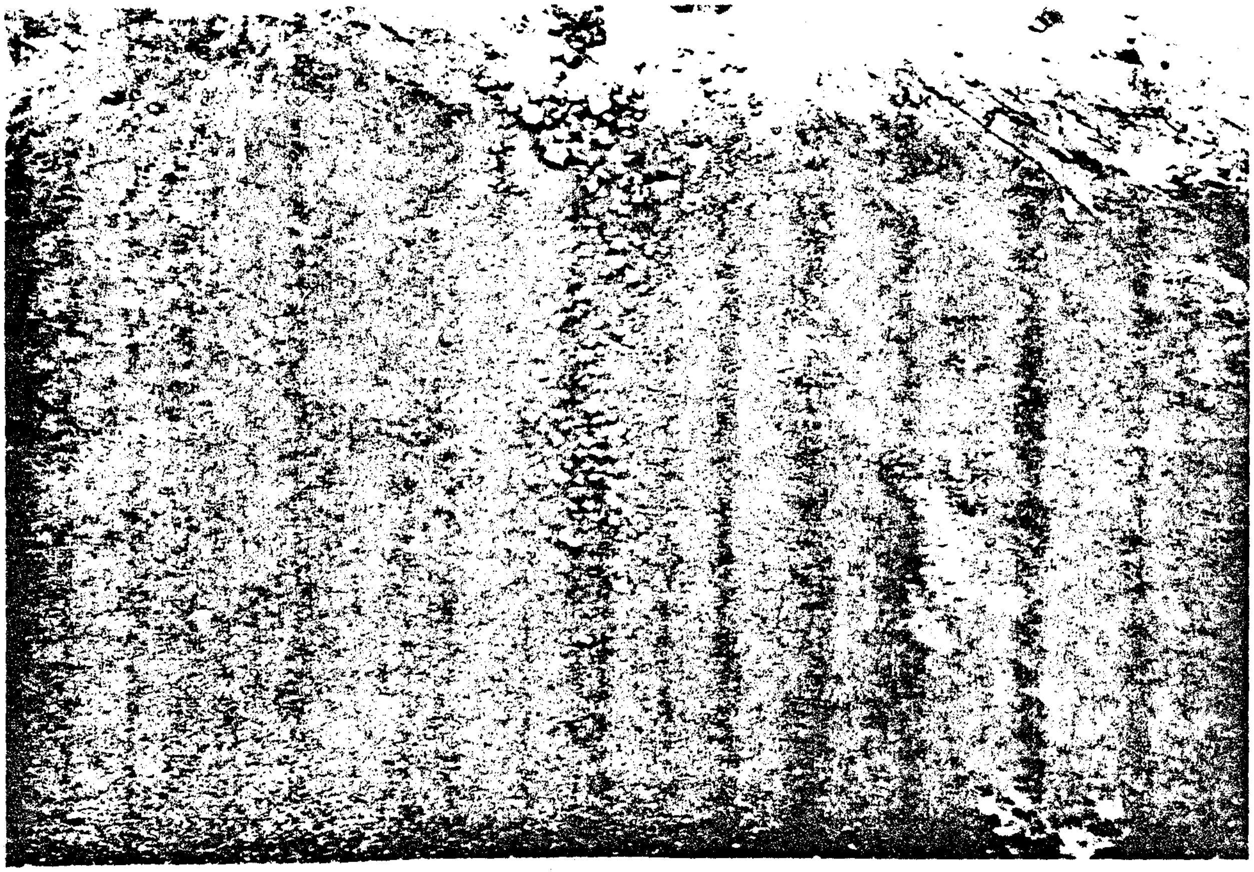


Figure D6. AreaVII on Figure D1. Flat slate occurs on the right.

Figure D7. An example of the sandstone cliffs on the northwestern corner of CNM.

E. Additions to the CNM Intertidal Zone Species List

Plants: by J. Lopez. Taxonomy follows Abbott and Hollenberg's Marine Algae of California (1976) Stanford University Press.

CHLOROPHYTA

1. Bryopsis pinnatula J. Agardh
   Very rarely occurs in lower intertidal zone on southern portion of the monument.

2. Ulva rigida C. Agardh
   This species is easily confused with U. californica but has toothed margins and a firm thallus. It frequently occurs as a pioneer species on newly exposed rock in the low to upper intertidal zone and is widespread on tidal benches and upper intertidal rocks from spring to fall.

PHAEOPHYTA

1. Analipus japonicus (Harvey) Wynne
   Although this species is common in Central California, it has only been identified from the lower intertidal area of the southern portion of CNM. It occurs rarely on rock surfaces.

2. Cystoseira setchelli Gardner
   This species occasionally is found in the southern portion of CNM along with the more common C. osmundacea in the lower intertidal zone.

3. Sphacelaria didichotoma Saunders
   This species is indistinguishable from S. californica in the field and occasionally occurs with it as an epiphyte on Corallina sp. in the mid-intertidal zone.

RHODOPHYTA

1. Binghamia californica J. Agardh
   This species occurs as a straw-colored slender, filiform, dichotomously branched variety in this area. It is frequently found as an epiphyte on corallines in the exposed lower to mid-intertidal zones.

2. Champia parvula (C. Agardh) Harvey
   Very rarely found on mid-intertidal algal mat as an epiphyte; easily confused with Binghamia californica but can be distinguished due to the absence of septa in latter species.

3. Chondria arcuata Hollenberg
   This species of Chondria is sometimes found on sand shelves below or adjacent to Phyllospadix cover during spring. It is easily overlooked due to the fact that a major portion of the plant is usually covered by fine sand.

4. Cryptopleura rosacea Abbott
   Occasionally found growing below Phyllospadix cover in low intertidal zone along with C. crispa and C. violacea.

5. Cryptopleura violacea (J. Agardh) Kylin
   Infrequently found with the more common C. crispa below Phyllospadix cover in the low intertidal zone.

6. Gelidium coulteri Harvey
   Like G. pussilum this species is frequently associated with upper mid-intertidal colonial invertebrates. It was one of only a few algal species growing in clumps from massive Phragmatopoma californica colonies in the southern CNM area.

7. Hypnea johnstonii Setchell & Gardner
   Frequently found as an epiphyte on corallines in the algal mat habitat. Distinguished from H. valentiae by its coarser appearance and matted branching.

8. Porphyrella californica Hollenberg
   This species was very common on upper intertidal barnacle rocks during the spring of 1977 but was absent in the previous year.

Animals: by R. Shaver.

PORIFERA (sponges)

1. Xestospongia vanilla
   White, en rusting "cake frosting" sponge.

2. Hymeniacidon spp.
   Appears as strands of papillae-like projections, cinnamon brown color.

3. Leucosolenia spp.
   White, fuzzy, solitary sponge.

4. Mycale macginitiei
   Smooth, brown, encrusting sponge.

5. Plocamia karykina
   Bright red, encrusting sponge.

6. Unidentified encrusting sponges
   a. Dirty white, prominent oscula.
   b. Clear sponge, transparent, smooth, associated with Euherdmania claviformis.

ECTOPROCTA (bryozoans)

1. Cauloramphus spiniferum
   Long spines around lorica, common.

2. *Figularia hilli*
   Small, grey to red, abundant.

3. *Crisia maxima*
   White, upright, branching.

4. *Eurystomella bilabiata*
   Red, derby-shaped aperture.

5. *Membranipora fusca*
   Brown.

6. Unidentified ectoprocts
   a. One spine per individual, pink color
   b. Individuals arranged in radiating lines, grey color
   c. Brown upright branching

UROCHORDATA (tunicates)

1. *Euherdmania claviformis*
   Aggregated individuals, transparent, elongated stalks with common base.

2. *Cnemidocarpa finmarkiensus*
   Small, red, broadly attached, solitary.

3. *Ascidia paratropa*
   Transparent, green, solitary, rare.

F. Management Considerations and Recommendations

1. The resource. It is the opinion of the investigators involved in this project that the CNM intertidal biota provide an ecological resource whose value is not exceeded elsewhere in San Diego County. The combination of a varied and relatively natural coastal habitat with a diversity of plants, animals, and ecological communities gives the area a high esthetic, educational, and scientific value.

Ecologically, its value is high, not because its beaches are pristine, but because the impact of man is low relative to other County beaches. At CNM, the intensive degradation is limited to local areas where use is heaviest, i.e. near the public access. Algal cover and animal populations are noticeably reduced where trampling is most frequent. Milder degradation has probably occurred throughout the Monument's intertidal zone, but, since pristine reference points are lacking, the extent of human impact is difficult to access. The scarcity of large animals of desirable species (lobsters, abalone, etc.) in the intertidal zone is evidence that depletion occurs despite current control measures. Even with these signs of human impact, the CNM intertidal zone is a valuable reference point for comparison with other more accessible and less restricted beaches, such as Sunset Cliffs and False Point.

2. Sensitivity of the resource. There is no question that human-caused mortality exists at CNM. In order to develop a management plan it is necessary to know how rapidly populations recover from natural and man-caused disturbances. The biota have various adaptations to natural "disturbances" which occur when waves bombard the substrate, when rocks move about and abrade one another, when hot dry weather coincides with low daytime tides, etc. Some species avoid mortality by living in armored houses; others seek refuge in crevices or under boulders. Those that cannot avoid damage tend to have rapid recovery rates--through vegetative reproduction or rapid recruitment from the plankton. These adaptations also serve to lessen the impacts of public use, since trampling, rock turning, and other abuses are somewhat similar to the natural mortality-causing factors, i.e. a physical (rather than chemical) impact is involved. One probable difference in natural and human disturbances, however, is that for animals and some plants, natural physical forces would tend to be most disruptive to smaller or younger individuals, while some human disturbances would select for the larger individuals. Such size-selective disturbances will alter the size structure of populations more than their densities. And because of the concentration of mortality on large individuals, the effects of human-caused mortality will be highly visible. Human use adds to the natural mortality rates of many species and also alters size distributions of "attractive" species.

The task of this research group has been to estimate how much human disturbance the intertidal biota can tolerate. Our findings, summarized in part B, demonstrate that tolerance depends on the species being abused. In turn, our perception of "tolerance" depends on the coinciding natural disturbances which occurred while experiments were underway. The intertidal zone has a highly variable environment which may be hostile when hot, dry weather coincides with low tides or benign when haze protects the biota from heat and desiccation. Our year of experimentation was not a particularly hostile one; this suggests that human-caused mortality may have been more tolerable, since natural mortality was not at a maximum. Because of the uncertainties of a variable environment, the results acquired in a short-term investigation cannot be used as absolute determinations of tolerance. However, they can and should be used as relative indicators of tolerance. For instance, 100 footsteps on an algal mat may be the threshold for damage in 1978 but not in a different year. However, the general rule that a few steps will probably be unnoticed but a 10-fold increase will cause damage will usually apply. Also, the ranking of species in order of sensitivity should be similar from year to year.

As indicated above, current levels of public use are causing measurable mortality to plant and animal populations near the access. In order to understand the long-term implications of public use, it is necessary to determine the recovery rates for the affected organisms. As our experiments with rock turning and algal trampling have shown, many species which are sensitive to disturbance are also quick to reinvade after disturbance is halted. And, as discussed in section B, the rapid recovery rates noted are no doubt due to the abundance of undisturbed areas nearby which serve as sources of offspring. The larger the disturbed area the longer will be the distance to a reproducing colony from which offspring must be drawn, and the slower the recovery.

Size and growth rates of species also influence recovery of damaged areas. Large species usually have slower growth rates, and several years will be required for damaged populations to return to their normal size distributions. Highly desirable species, such as lobsters and abalone, are rarely found in large sizes at CNM in the intertidal zone, presumably due to poaching. Large empty shells are rare as well, and one wonders what a beach without shell collectors would look like. Moderately attractive species, such as mussels and owl limpets are still present in sizes which are much larger than most San Diego beaches. However, we don't know if these are the largest sizes attainable, since CNM populations too may be affected by human disturbance. For large species to recover from disturbance--especially from disturbances which select for the largest individuals--several years will be required for recovery.

3. Management recommendations. The value of the intertidal biological resources of CNM is sufficiently great that major management goals should be to maintain and enhance that value. Maintaining the resource will require some reduction in the amount of public use. Enhancing the value will require additional restriction of the types of activities in the intertidal zone and reducing the area where people use is permitted. Obviously there are constraints which must be recognized in working toward these goals. Controlling public use requires enforcement officers and this is expensive. Secondly, it must be realized that the area can never be "pristine" even if public use were entirely prohibited, since there would always be some effects of the surrounding human population, through altered chemical composition of the water (sewage and other additions), through offshore fishing, through noise pollution, etc. The management goal should be to provide as natural an environment as is possible within these constraints.

How much use: During low tides, it is not uncommon to find over 50 people in the intertidal zone at a single time. If they enter and leave by the same path, they could cause 100 steps-worth of damage to the biota on that path. The number present on a single day is enough to cause significant localized reductions in algal cover, barnacles, and other fauna, as shown in our trampling experiments. Heaviest use remains close to the access, so that trampling, rock turning, handling animals, and other disturbances are most frequent there. Further away, people density is lower, and the probability of a single spot receiving dozens of footsteps per day is greatly lessened.

Current visitor use exceeds the carrying capacity at the access. Even with greatly reduced visitor use--say to 10-20 visitors per day--some changes would be seen at the access path. However, the area involved would be smaller, since the people would probably fan out less and cover less ground. Before making a specific recommendation concerning visitor density, the questions of location and types of activities will be considered.

Where to allow use: The habitats inventoried in this study all harbor species susceptible to depletion either through trampling or intentional damage. Cliff faces are readily available for plucking limpets and periwinkles. Wherever flat benches occur, there are algal mats which are sensitive to trampling. Barnacle rocks are sought for sure footage and the animals suffer from trampling. *Mytilus* and *Pelvetia* rocks are usually larger and lower in the intertidal zone and hence not trampled, but intentional damage to the larger plants and animals occurs. *Phyllospadix* pools and other pools are popular for fishing and picking up animals.

Of all the habitats considered in this study, the sandy beach was least abused. Presumably this was because most people had come to see the tide pools. The sandy beach is probably the least sensitive of the habitats, since few large animals and no macroscopic algae are residents. Accumulations of rotting kelp offer habitat for fauna from time to time, but these are rarely damaged by the public.

Because of the biological attractions of all habitats (except possibly the sandy beach), it would seem impossible to allow visitors to the intertidal zone without accepting some damage to the biota. Most of the damage would have short-term effects, but damage to large, slow-growing species would alter the appearance of these populations and reduce their reproductive potential for long periods of time. With larger areas being disturbed, we predict that the short-term effects would become longer-term effects as reproductive stocks become depleted.

In order to allow the maintenance and enhancement of the CNM intertidal biota, public use should be restricted to a small area, with boundaries marked and enforced. Possibly the area should be located adjacent to Grunion Beach, so that people who might want only to walk around the tide pools could do so in comfort and without damaging the rocky biota. Restriction of use to a small area would increase the damage at that spot but would provide greater insurance that the bulk of CNM would be able to recover from public use, as well as provide offspring for recolonization of the used area.

Location of the public use area near the southern end of Grunion Beach would be desirable from two standpoints. First, the area would be readily visible from the existing parking lot, and enforcement of rules would be easier. Secondly, the long path to the access would be eliminated. While the length of this path may deter some visitors from seeking out the tide pools, any benefits gained from their absence seem to be exceeded by damages to the CNM cliffs. Since the access near the parking lot was fenced off, the path to the northern access has widened extensively and stabilizing vegetation has been denuded. Rains have added to the erosion by washing the loose sediments onto the beach. Damage to the natural arch has occurred, and its continued existence is questionable, especially with human abuse.

A public access at the parking lot would require construction of a stairway to the beach, which would be costly. However, it would also restrict the access path to a single location and reduce trampling effects enroute the beach. Wave force will cause damage to such a stairway from time to time, and maintenance funds would be required. Some type of easily repaired or replaced stair would seem more desirable than a massive concrete structure.

If the recommendation to change the access cannot be implemented, then the present access path along the cliff should be fenced to channel people along a narrower area.

What kind of use: The kinds of abuses that occur are listed in section A and include destruction of plants, animals, and substrate. Obviously these activities should be eliminated. The rangers do a good job of controlling the public when present, but increased enforcement manpower is needed. The job would be easier with use restricted to a small area near the parking lot. Our experience was that organized groups tended to be more careful--although they probably handled more organisms since they know better where to find them--than did the general public. As if often the case, the irresponsible few are the most destructive.

To educate the irresponsible, additional signs are recommended--not only to list rules but to instruct the public on the need for the rules. The tide pool brochure, prepared by Ted Turk for this project, is a start, but attractive picture-signs at the parking lot would probably receive more attention. In addition, if enough information were provided (i.e. sample shells, algae, etc., as in a museum display), it is possible that many visitors would forego the hike down to the beach, being assured that most people won't be able to find an octopus anyway. Perhaps some permanently mounted spotting scopes would provide the desired close look without risk of falling down and getting wet.

Attractive display signs would, of course, be targets for vandalism, and their location near the parking lot and beach access would make it easier for a single ranger to supervise all activities.

Specific recommendations: Drawing together all of the above considerations, our recommendations may be summarized as follows.

1. Visitors should be made aware that the CNM intertidal zone supports an ecologically, esthetically, educationally and scientifically valuable resource. This message should be provided on pictorial signs as well as with the intertidal brochure.

2. Users should be made aware that most visitor activities--even simply walking on organisms--will result in mortality to the organisms which make up that resource.

3. The area available for public use should be restricted to one small but representative area near the parking lot. Markers should be easily visible and limits should be enforced with additional manpower.

4. Spotting scopes (coin-op if necessary) should be located at the cliff edge to encourage visitors to look from a distance.

5. A stairway should be constructed to control the location of access to the beach; if possible, it should be as inobstrusive as possible and easily repaired following predictable damage from storm waves.

6. Research into the long-term effects of public use should be allowed, and a long-term monitoring of resources is advised. This is desirable in order to assess the effects of the recommended management program.

Acknowledgements:

We thank the National Park Service for financial support of the 1976 and 1977 projects. Superintendent Tom Tucker of the Cabrillo National Monument has been most supportive of our research efforts, and his helpful attitude toward our work is greatly appreciated. He and Ranger Larry Wiese have added greatly to our understanding of the management problems at CNM, and we wish to acknowledge their contributions to our project with gratitude. We also thank the other monument personnel whom we have encountered during the study for their cooperation, courtesy and help.

We are indebted to Kristine Creed for typing and Troy Davis for assistance in summarizing data and preparing the graphics. The air photos were taken by James Curtis with the assistance of the pilot, Thomas Meyer, both of whom donated their time and skills.